FORMS FOR ARCHITECTURAL CONCRETE

PORTLAND CEMENT ASSOCIATION

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FOR
ARCHITECTURAL CONCRETE

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FOREWORD

THERE is little in American literature and not much more in foreign publications regarding forms for concrete construction. This situation is no doubt due, in part at least, to the familiarity of most contractors with formwork for structural concrete. The use of concrete as an *architectural* material, with which many contractors are inexperienced, is now developing rapidly. The technique and craftsmanship of the form construction involved is quite different from that for structural concrete, although fundamentally the same principles apply. In order to meet the demand for information pertaining strictly to form-work for architectural concrete buildings, this booklet has been prepared. Only those phases of form construction that apply especially to architectural concrete have been included. Not every conceivable detail has been shown, but important phases have been covered with sufficient examples and suggestions to enable the careful contractor, though inexperienced in architectural concrete, to produce a thoroughly satisfactory job.

Portland Cement Association

Forms for Architectural Concrete

SECTION I—INTRODUCTION

WHEN CONCRETE WAS USED only as a structural material and it was planned to cover it with brick, stone or marble, the function of the formwork was simply to mold and support the concrete until it had attained sufficient strength to support itself. Little attention was given to perfection of form construction or to the material of which the forms were built in order to obtain a good looking job. The main requisite was adequate strength to resist the weight and pressure of the concrete.

In the latter part of the nineteenth century, concrete began to be used as an architectural material in buildings. Comparatively few buildings of this type were constructed, however, until the turn of the century, so the possibilities of architectural treatment by means of formwork were not fully appreciated until recently. Because concrete records permanently every detail, good or bad, of the contact surface of the forms, more and more attention is now being given to form construction. Technique and craftsmanship have improved and developed until, by the selection of form material and by the use made of it, a wide variety of surface textures and details are now obtained which are in keeping with any architectural style.

Every effort was made in the earlier buildings to produce smooth surfaces. It was considered objectionable to have the forms leave an impression of the joints between boards, or to use lumber that left a decided grain marking in the concrete. Following the period of smooth textures, there was an inclination on the part of some designers to swing in the other direction until the opposite extreme was reached and unusually rough textures were occasionally used. Out of these trends has come a knowledge of form building and of form materials for architectural concrete work, which places at the disposal of the architect a range of textures from those of glass-like smoothness, produced with special liners or metal molds, to those rugged textures obtained with rough-sawed lumber in which the grain has been artificially raised by soaking with water or ammonia. Plaster waste molds and milled wood forms make the forming of intricate details, as well as the simplest, economically possible.

Architectural concrete forms do not differ fundamentally in design and construction from those for ordinary structural concrete. The difference is in the selection of materials and in the craftsmanship used in the form building to properly produce in the finished structure the architect's conception of how the building should appear. The primary object of the forms is no longer simply one of supporting the unhardened concrete, but combined with that object is the important purpose of giving character to the structure through form, texture and detail. Because concrete left exposed is the architectural medium, extra care is warranted to achieve perfection in every operation of construction including the form building.

Fig. 1—The south or planetarium tower, Griffith Observatory, Los Angeles, reflects in pleasing texture and sharp details the value of careful form construction and rigid control in mixing and placing concrete. Austin and Ashley, architects; Wm. Simpson Construction Co., contractor.

SECTION II—STRUCTURAL DESIGN

Forms must be designed to have adequate strength in bending and shear to withstand the pressure of the freshly-placed concrete without failure of any of the component parts. It is also necessary to keep the deflection of sheathing, studs and wales within certain prescribed limits. It is much more important to keep the deflection of the forms for architectural concrete within small limits than it is for a structural job, where appearance is not such an important factor.

In order to design forms correctly, due consideration must be given to the loads or pressures to which the forms are subjected; to the allowable working stresses for the materials used; to the modulus of elasticity of the material; and to the permissible deflection.

Pressures

Forms for architectural concrete are usually of the wall or vertical type; therefore the horizontal pressure exerted by the concrete is the load for which the forms must be designed. There is some uncertainty as to the exact pressure exerted by freshly-placed concrete, but experience, supported by some test data, indicates with sufficient accuracy for practical purposes the pressures that should be used for safe design.

The pressure is influenced by the following factors which should be taken into account by the designer:

1. Method of placing concrete, whether by hand or by vibration.
2. Rate of filling the forms.
3. Temperature of the concrete.

The consistency and proportions of the mix also have an appreciable effect upon the pressure because of their influence on the fluidity of the concrete. The evaluation of these factors, however, is difficult and, as a rule, can be neglected within the range of mixes used in building construction. Likewise, the size and shape of the forms and the amount and disposition of reinforcement are factors that are generally neglected without harm.

High-frequency vibration is being quite widely adopted as a means of placing structural concrete and, to some extent, in architectural concrete work. Tests* show that vibration causes concrete to act as a fluid and the fluidity is retained during the vibration period. Thus, the full height of concrete under vibration must be considered as the head, and the pressure exerted is the same as for a liquid having the weight of concrete, which may safely be assumed as 145 p.c.f.**

When concrete is compacted by hand, the agitation is not sufficiently rapid to maintain the mass in strictly a fluid condition. The pressures exerted are therefore somewhat less than the full hydrostatic head. Tests show that, for each rate of placing, the pressure increases to a certain maximum and then decreases. The more rapid the placing rate, the quicker the maximum pressure is attained, because the concrete becomes so compacted after it has reached a certain depth (variable depending upon the rate of placing) that it will support any additional depth of concrete without exerting additional pressure on the forms. This state is reached, when placing at a rapid rate, before hardening of the concrete has begun; but for slower rates, probably under two or three feet per hour, the hardening of the concrete combines with the compaction to prevent further increase in pressure.

The temperature at which concrete is placed also has a marked influence on the maximum pressure attained and the elapsed time before it is reached. For example, mixtures placed at 70° F. develop maximum pressures equal to about 75 per cent of those placed at 50° F. Fig. 2*** shows conservative pressures for concrete placed at rates from 2 to 6 ft. per hour and at temperatures of 70° and 50° F. Forms of less depth than the depth at which maximum pressure is attained for the different rates of placing should be designed to withstand the pressures indicated by the full lines. In deep forms, that part below the depth of maximum pressure should be

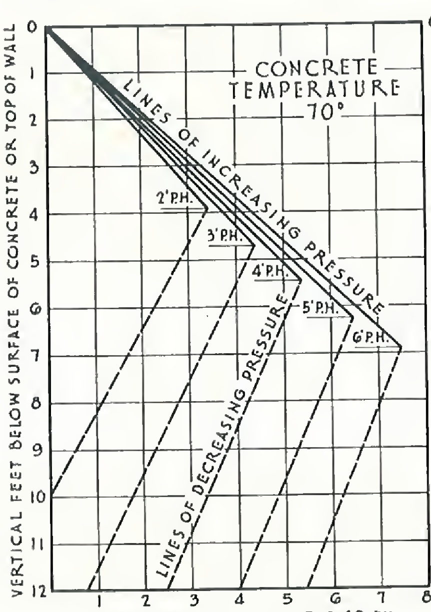

Fig. 2a

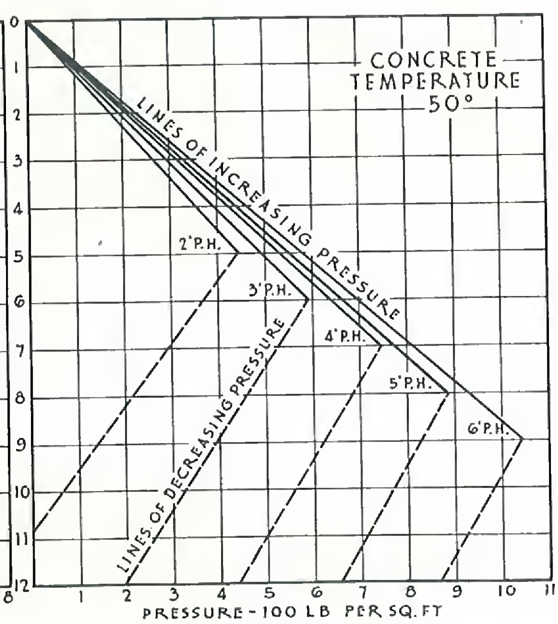

Fig. 2b

*"The Effect of Vibration on the Pressure of Concrete Against Formwork" by L. W. Teller, *Public Roads*, March, 1931, Vol. 12, No. 1, page 11. "Compaction of Concrete Through the Use of Vibratory Tampers," Raymond E. Davis and HarmerE. Davis, *Journal, American Concrete Institute*, June, 1933, Vol. 4, No. 9, pg. 365.

**p.c.f.—pounds per cubic foot.

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designed for the maximum pressure as indicated by the change in direction of the lines of pressure. Generally, building forms of such depth as to require that the bottom part be designed for the maximum pressure are constructed with the same spacing of studs and wales to the top. Some saving in material can be made in long, high walls by taking advantage of the lower pressure near the top, but this is seldom of importance in ordinary buildings.

Allowable Stresses

Formwork, being temporary, may be designed for somewhat higher working stresses than would be allowed for permanent construction. It is not advisable to go to extremes, however, because forms may be overloaded due to an unexpected rapid rate of placing or for some other reason, and the result of a form failure caused by overstressing is very troublesome to correct. Theoretically, the kind of lumber used makes some difference in the allowable design stresses, but for those kinds of lumber generally used, an extreme fiber stress of 1800 p.s.i.* and a horizontal shear of 200 p.s.i. may be used. If the higher strength woods such as Douglas fir and Southern pine cannot be obtained, and one of the woods considerably lower in strength must be used, some adjustment should be made in the working stresses. Table 1 gives safe working stresses for form design for the various kinds of lumber.

*p.s.i.—pounds per square inch.

TABLE No. 1—Safe Working Stresses and Moduli of Elasticity of Various Kinds of Lumber for Form Construction**

Kind	Extreme Fiber in Bending	Compression Perpendicular to Grain	Compression Parallel to Grain $L/d \leq 10$ ***	Horizontal Shear	Modulus of Elasticity
Douglas Fir, Coast Region	1800	480	1650	200	1,600,000
Hemlock, West Coast	1550	450	1080	150	1,400,000
Larch	1800	480	1650	200	1,300,000
Pine, Idaho White, Northern White, Sugar and Ponderosa	1100	375	1100	170	1,000,000
Pine, Norway	1300	450	1200	170	1,200,000
Pine, Longleaf and Shortleaf, Southern	1800	480	1650	200	1,600,000
Redwood	1450	375	1500	140	1,200,000
Spruce, Eastern	1300	375	1200	170	1,200,000

**The working stresses given in this table are approximately 50% greater than ordinarily used for permanent construction and for the grade and sizes of lumber generally used for forms, because forms are temporary and are subjected to full load for only a few hours at most, thereby minimizing the effect of time yield. If Inland or Rocky Mountain region Douglas fir is used, a reduction of about 10% and 30% respectively should be made in the tabulated working stresses for Douglas fir. Basic data for this table taken from Wood Structural Design Data, Vol. 1, by National Lumber Manufacturers' Association.

***L = length of member in inches; d = least dimension of the member in inches.

Fig. 3—The formwork for the California Fruit Growers Exchange, Los Angeles, an example of uniform spacing of studs and wales, even for high walls. Walker and Eisen, architects; Wm. Simpson Construction Co., contractor.

Figs. 4a & b—The wall texture at the right being rough will permit greater deflection of the form sheathing than the smooth surface shown at the left.

Deflection

Forms must be so designed that the various parts will not deflect beyond prescribed limits; otherwise, the finished wall will be out of alignment and unsightly bulges will mar the appearance. The exact amount of deflection permissible depends upon the desired finish and the location in the building. A small deflection that would not be noticeable in a texture produced with square-edged rough lumber is quite objectionable in a surface intended to be very smooth, and particularly in one made with a form liner to eliminate joint lines. If the surface is near the street level, or can be observed from a short distance, less deflection is permissible than in the upper stories where slight irregularities are not noticeable. Under any circumstances, the deflection of sheathing, studs and wales should not be greater than 1/270 of the span. As a rule, the size and spacing of studs and wales will be governed by the stresses in bending and horizontal shear, but the deflection of sheathing is generally the determining factor.

In the formulas given below for deflection, the modulus of elasticity of the material appears. The modulus of elasticity of each of the various kinds of lumber has been determined by tests. It is evident from a study of these values (Table 1) and the formulas for deflection, that for the same loads and span some woods will deflect much more than others. Due consideration should be given to this fact in the selection of lumber, particularly for sheathing.

For a uniform load such as carried by sheathing or studs and for a single span,

$$D \text{ (deflection in inches)} = \frac{5wl^4}{384 \times 12 \times EI} \qquad (1)$$

TABLE No. 2—Properties of American Standard Board, Plank, Dimension and Timber Sizes Commonly Used for Architectural Concrete Form Construction*

Nominal and Rough Sizes in Inches	American Standard Sizes in Inches			Area of Section $A=bh$ Sq. In.				Moment of Inertia $I=\frac{bh^3}{12}$				Section Modulus $S=\frac{bh^2}{6}$				Board Feet Per Lineal Foot of Piece
b h	*S2S* b h	*S2E* b h	*S4S* b h	Rough	*S2S*	*S2E*	*S4S*	Rough	*S2S*	*S2E*	*S4S*	Rough	*S2S*	*S2E*	*S4S*	
4x1	4x25/32	3 5/8x1	3 5/8x25/32	4.0	3.12	3.63	2.83	.33	.16	.30	.14	.67	.41	.61	.37	1/3
6x1	6x25/32	5 5/8x1	5 5/8x25/32	6.0	4.69	5.63	4.40	.50	.24	.47	.22	1.00	.61	.94	.57	1/2
8x1	8x25/32	7 1/2x1	7 1/2x25/32	8.0	6.25	7.50	5.86	.67	.32	.63	.30	1.33	.82	1.25	.76	2/3
10x1	10x25/32	9 1/2x1	9 1/2x25/32	10.0	7.81	9.50	7.42	.83	.40	.79	.38	1.67	1.02	1.58	.97	5/6
12x1	12x25/32	11 1/2x1	11 1/2x25/32	12.0	9.38	11.50	8.98	1.00	.48	.96	.46	2.00	1.22	1.92	1.17	1
4x1 1/4	4x1 1/16	3 5/8x1 1/4	3 5/8x1 1/16	5.0	4.26	4.53	3.85	.65	.40	.59	.36	1.05	.75	.95	.68	5/12
6x1 1/4	6x1 1/16	5 5/8x1 1/4	5 5/8x1 1/16	7.5	6.38	7.03	5.98	.98	.60	.92	.56	1.56	1.13	1.47	1.06	5/8
8x1 1/4	8x1 1/16	7 1/2x1 1/4	7 1/2x1 1/16	10.0	8.51	9.37	7.97	1.30	.80	1.22	.75	2.08	1.51	1.96	1.41	5/6
10x1 1/4	10x1 1/16	9 1/2x1 1/4	9 1/2x1 1/16	12.5	10.63	11.90	10.09	1.63	1.00	1.55	.95	2.62	1.89	2.48	1.79	1 1/24
12x1 1/4	12x1 1/16	11 1/2x1 1/4	11 1/2x1 1/16	15.0	12.79	14.40	12.22	1.96	1.20	1.88	1.15	3.13	2.26	3.00	2.16	1 1/4
4x1 1/2	4x1 5/16	3 5/8x1 1/2	3 5/8x1 5/16	6.0	5.25	5.44	4.76	1.12	.76	1.02	.68	1.50	1.16	1.36	1.04	1/2
6x1 1/2	6x1 5/16	5 5/8x1 1/2	5 5/8x1 5/16	9.0	7.87	8.44	7.38	1.69	1.13	1.58	1.06	2.25	1.73	2.11	1.62	3/4
8x1 1/2	8x1 5/16	7 1/2x1 1/2	7 1/2x1 5/16	12.0	10.50	11.25	9.84	2.25	1.51	2.11	1.41	3.00	2.31	2.82	2.15	1
10x1 1/2	10x1 5/16	9 1/2x1 1/2	9 1/2x1 5/16	15.0	13.13	14.25	12.47	2.81	1.89	2.67	1.79	3.76	2.89	3.57	2.73	1 1/4
12x1 1/2	12x1 5/16	11 1/2x1 1/2	11 1/2x1 5/16	18.0	15.78	17.25	15.09	3.37	2.27	3.23	2.17	4.50	3.46	4.32	3.30	1 1/2
4x2	4x1 5/8	3 5/8x2	3 5/8x1 5/8	8.0	6.50	7.25	5.89	2.66	1.43	2.42	1.30	2.67	1.76	2.42	1.60	2/3
6x2	6x1 5/8	5 5/8x2	5 5/8x1 5/8	12.0	9.75	11.25	9.14	4.00	2.15	3.75	2.01	4.00	2.64	3.75	2.48	1
8x2	8x1 5/8	7 1/2x2	7 1/2x1 5/8	16.0	13.00	15.00	12.19	5.33	2.87	5.00	2.68	5.33	3.51	5.00	3.30	1 1/3
10x2	10x1 5/8	9 1/2x2	9 1/2x1 5/8	20.0	16.25	19.00	15.44	6.66	3.58	6.34	3.40	6.67	4.40	6.35	4.18	1 2/3
12x2	12x1 5/8	11 1/2x2	11 1/2x1 5/8	24.0	19.50	23.00	18.69	8.00	4.30	7.67	4.11	8.00	5.28	7.66	5.06	2
2x4	1 5/8x4	2x3 5/8	1 5/8x3 5/8	8.0	6.50	7.25	5.89	10.68	8.65	7.94	6.45	5.33	4.32	4.38	3.56	2/3
2x6	1 5/8x6	2x5 5/8	1 5/8x5 5/8	12.0	9.75	11.25	9.14	36.00	29.25	29.65	24.10	12.00	9.75	10.54	8.57	1
2x8	1 5/8x8	2x7 1/2	1 5/8x7 1/2	16.0	13.00	15.00	12.19	85.33	69.33	70.31	57.13	21.33	17.34	18.75	15.23	1 1/3
2x10	1 5/8x10	2x9 1/2	1 5/8x9 1/2	20.0	16.25	19.00	15.44	166.67	135.41	142.89	116.10	33.33	27.14	30.08	24.44	1 2/3
2x12	1 5/8x12	2x11 1/2	1 5/8x11 1/2	24.0	19.50	23.00	18.69	288.00	234.00	253.48	205.95	48.00	39.00	44.08	35.82	2
3x6	2 5/8x6	3x5 5/8	2 5/8x5 5/8	18.0	15.75	16.88	14.77	54.00	47.25	44.48	38.93	18.00	15.77	15.81	13.84	1 1/2
3x8	2 5/8x8	3x7 1/2	2 5/8x7 1/2	24.0	21.00	22.50	19.69	128.00	112.00	105.46	92.29	32.00	28.03	28.13	24.61	2
3x10	2 5/8x10	3x9 1/2	2 5/8x9 1/2	30.0	26.25	28.50	24.94	250.00	218.75	214.41	187.55	50.00	43.75	45.13	39.48	2 1/2
3x12	2 5/8x12	3x11 1/2	2 5/8x11 1/2	36.0	31.50	34.50	30.19	432.00	378.00	380.22	332.69	72.00	63.00	66.13	57.86	3

NOTES: b = width of piece or dimension perpendicular to direction of load.
h = depth of piece or dimension parallel to direction of load.
S4S—all figures under this heading apply also to pieces *S1S1E*, *S1S2E* and *S2S1E*.
*Basic data for this table taken from Wood Structural Design Data, Vol. 1, by National Lumber Manufacturers' Association.

in which

w = uniform load per lineal foot in pounds

l = span in inches, center to center of supports

E = modulus of elasticity

I = moment of inertia (See Table 2—use the proper value, depending on whether the lumber is rough, *S2S, S2E or S4S*).

If the sheathing or studs are continuous over more than one span, which is usually the case, the deflection may be taken as the average of the deflection of a simple span and one fixed at the supports, or

$$D = \frac{3wl^4}{384 \times 12 \times EI}. \quad (2)$$

Problem 1—Determine the maximum deflection of 1x6 Long Leaf Yellow pine sheathing *S4S*, if studs are spaced 18-in. centers and concrete at 70° F. is placed at the rate of 5 ft. per hour. Sheathing continuous over several studs. (See Fig. 5.) Assume the form to be 10 ft. deep. Because the form is deeper than the depth at which maximum pressure will be exerted at the prescribed placing rate, the entire form will be designed for the maximum pressure of 650 p.s.f. (Fig. 2a).

$w = 650 \times .47 = 306$ p.l.f.*

$l = 18$ in.

$E = 1{,}600{,}000$ (Table 1)

$I = .22$ (Table 2)

$$D = \frac{3 \times 306 \times 18^4}{384 \times 12 \times 1{,}600{,}000 \times .22} = .06.$$

The permissible D is not more than $\frac{18}{270} = .067$; therefore, the size boards for the span and load assumed is satisfactory as far as deflection is concerned. It is seldom necessary to determine the stress in sheathing due to bending and shear. The method of determining such stresses, which is discussed in the following paragraphs and illustrated by Problem 2, is also applicable to sheathing.

Bending and Shear

Sheathing and studs may be simply supported at two points, but much more commonly they are continuous over several spans. If simply supported, the bending moment is

$$M = 1.5wl^2 \quad (3)$$

and when continuous over more than two spans,

$$M = 1.2wl^2 \text{ (approx.)} \quad (4)$$

in which M = bending moment in inch pounds

w = uniform load per lineal foot in pounds

l = span in feet, center to center of supports.

The resisting moment of the member being designed is

$$M_r = fS \quad (5)$$

in which M_r = resisting moment in inch pounds

f = allowable stress in extreme fiber in bending (Table 1)

S = section modulus of the member $\frac{bh^2}{6}$ (Table 2)

*p.l.f.—pounds per lineal foot.

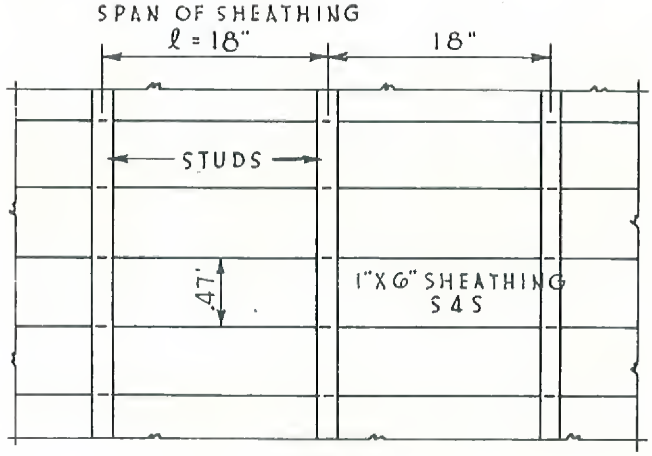


Fig. 5

Since the resisting moment must equal the bending moment, the allowable span is determined by equating $M_r = M$ and solving for l, thus:

$$fS = 1.5wl^2$$

$$l = \sqrt{\frac{fS}{1.5w}} \quad (6)$$

or

$$fS = 1.2wl^2$$

$$l = \sqrt{\frac{fS}{1.2w}}. \quad (7)$$

Likewise, the maximum allowable load, depending on the degree of continuity, can be obtained as

$$w = \frac{fS}{1.5l^2} \text{ or } w = \frac{fS}{1.2l^2}.$$

For short spans and heavy loads, the shear on the member at the supports (at the studs in the case of sheathing and at the wales in the case of studs) may determine the size of member required. It is sufficiently accurate for all conditions of continuity to compute the shear as

$$V = \frac{lw}{2} \quad (8)$$

in which V = shear in pounds

w = uniform load in pounds per lineal foot

l = span in feet center to center of supports.

The unit shearing stress on the member, which must not exceed the allowable horizontal shear (Table 1), is

$$v = \frac{1.5V}{bh} \quad (9)$$

in which v = unit shearing stress in p.s.i.

b = actual thickness of the member in inches

h = actual depth of the member in inches.

By substituting the value of V (Eq. 8) in Equation 9, the allowable span is determined in terms of v, b and h.

$$l = \frac{4vbh}{3w} \quad (10)$$

or allowable load per lineal foot is

$$w = \frac{4vbh}{3l}. \quad (11)$$

Problem 2—Determine the maximum allowable spacing of wales, if 2x6 Long Leaf pine studs *S1S1E* are spaced 18-in. centers and concrete at 70° F. is placed at rate of 5 ft. per hr. Studs are continuous over several spans, and the form is assumed of such depth as to require it to be designed for the maximum concrete pressure. (Fig. 6.)

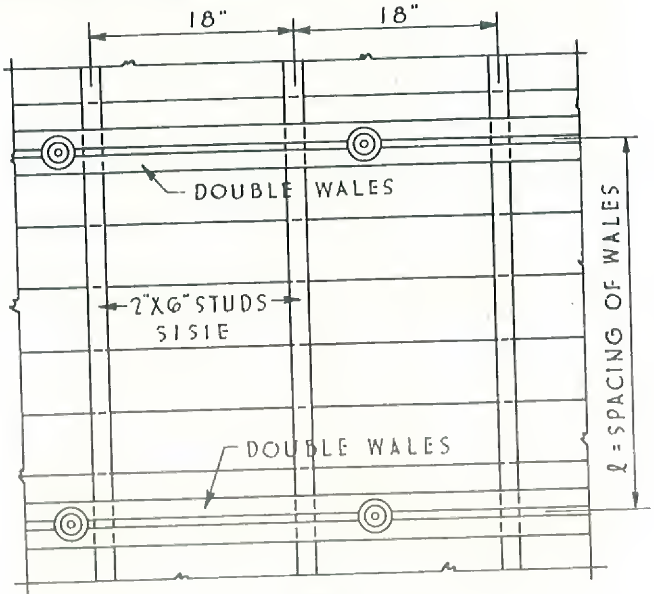


Fig. 6

$w = 650 \times 1.5 = 975$ p.l.f.	(Fig. 2)
$f = 1800$ p.s.i.	(Table 1)
$S = 8.57$	(Table 2—See footnote)
$v = 200$ p.s.i.	(Table 1)
$b = 1\frac{5}{8}$ in.	
$h = 5\frac{5}{8}$ in.	(Table 2)

To determine spacing of wales for bending, substitute in Formula 7

$$l = \sqrt{\frac{1800 \times 8.57}{1.2 \times 975}} = 3.62 \text{ ft., say 44 in.,}$$

for shear, substitute in Formula 10

$$l = \frac{4 \times 200 \times 1.625 \times 5.625}{3 \times 975} = 2.50 \text{ ft., say 30 in.}$$

The maximum spacing of wales will therefore be 30 inches.

Wales

Wales differ from studs and sheathing in that they support a group of concentrated loads, transmitted to the wales by the studs; so it is necessary to determine the bending moment and shear for a group of equal concentrated loads rather than for a uniform load.

The spans between ties should never exceed 60 in. (the maximum values given in the accompanying tables) and a maximum tie-spacing of 48 in. is preferable except in unusual cases. The spacing of ties and the dimensions of wales will be determined by the horizontal shear resistance of the wales or the stress in bending. Deflection is seldom a factor in wale design.

The maximum shear will be found when a stud is located immediately beside a tie, for which condition

$$V = P + \frac{P(l-a)}{l} + \frac{P(l-2a)}{l} + \text{---} \frac{P(l-(n-1)a)}{l} \tag{12}$$

in which

l = distance between ties in inches
P = each concentrated load in pounds
a = distance center to center of studs
n = number of studs between ties.

The unit shearing stress on the wales is found by Formula 9.

With satisfactory accuracy, the maximum bending moment may be considered to be under the center load of a group consisting of an odd number of equal concentrated loads when the center load is placed at the center of the span. Making allowance for continuity, the maximum moment will then be

$$\left.\begin{array}{ll} \text{for 1 load} & M = \dfrac{Pl}{5} \\ \text{for 3 loads} & M = \dfrac{4P}{5}\left(\frac{3}{4}l - a\right) \end{array}\right\} \tag{13}$$

There will seldom be more than three studs between ties; so one of the above formulas will be applicable for practically every case.

The resisting moment will be the same as given in Formula 5.

Problem 3—Determine the maximum allowable spacing of ties for double 2x6 Long Leaf pine wales *S1S1E* spaced 27 in. apart with studs spaced 16-in. centers. Pressure of concrete 600 p.s.f. (Fig. 7.)

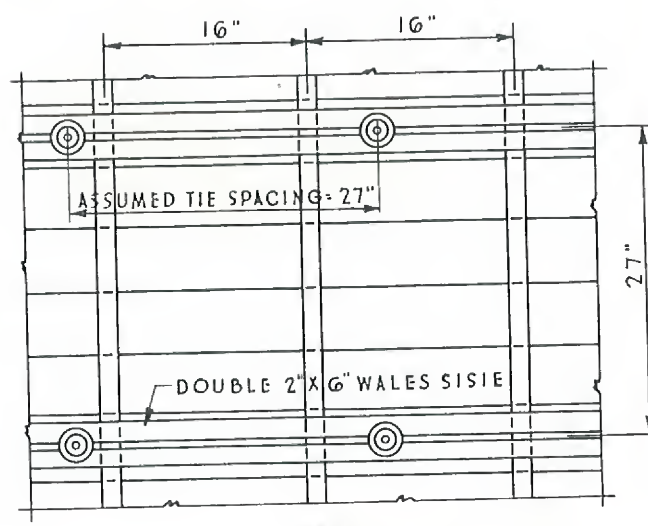


Fig. 7

The load carried to the wales by each stud will be

$$P = 600 \times 1.33 \times 2.25 = 1800 \text{ lb.}$$

Assume spacing of ties 27 in. and there will be a maximum of two studs between ties; therefore only

the first two terms of Formula 12 need be used to determine

$$V = 1800 + \frac{1800(27 - 16)}{27} = 2530 \text{ lb.}$$

and by Formula 9

$$v = \frac{1.5 \times 2530}{2 \times 9.14} = 206 \text{ p.s.i.}$$

This is very slightly in excess of the allowable horizontal shear (200 p.s.i. for Long Leaf pine); so the tie-spacing assumed would be considered satisfactory if the wales are not overstressed in bending.

Check for bending stress by substituting in Formula 13 for a single load midway between ties, thus;

$$M = \frac{1800 \times 27}{5} = 9700$$

and by Formula 5

$$f = \frac{9700}{2 \times 8.57} = 565 \text{ p.s.i.}$$

This stress is below the allowable in the extreme fiber; so the assumed tie-spacing is satisfactory.

Ties

The spacing of ties having been determined on the basis of the strength of the wales, the capacity of the ties must be checked against the allowable values given in the manufacturer's catalogue, or the required size of the ties must be computed. The most satisfactory tie for architectural concrete work, which will be more fully discussed later, is the ordinary pencil rod. The size rod required is easily computed by the formula

$$A_r = \frac{P}{f_s}$$

in which

A_r = cross-sectional area of pencil rod

P = pressure of concrete times the contributing area, namely the distance between wales multiplied by the distance between ties

f_s = allowable working stress for steel (25,000 p.s.i. for the temporary loads encountered in form construction).

If the capacity of the selected size tie is exceeded by the strength of the wales for a given spacing of ties, then the spacing must be reduced or the size of tie rods increased, whichever may be most economical, depending upon the contractor's equipment. Large ties are more difficult to remove from the concrete, which fact should be taken into consideration. One-fourth-inch and ⅜-in. round rods are most frequently used and ½-in. and ⅝-in. rods may occasionally be required. It is better, however, to reduce the spacing of the ties or wales to avoid using the larger sizes.

Design Tables

The formulas in the preceding pages can be used for the design of any forms; their use is necessary where special conditions are encountered, but for the average job, much time and labor can be saved by using tables for the safe spacing of studs, wales and ties such as Tables 3 to 8.* These tables are based upon allowable working stresses for Douglas fir and Long Leaf Southern pine. If used for woods of materially less strength, a reduction in the allowable spacing values should be made in proportion to the difference in working stresses.

Presdwood and plywood, the use of which will be fully discussed later, are used for form lining and sheathing where especially smooth surfaces free from joint lines are desired. Plywood ⅝ in. or more thick is used for sheathing without backing for pressures up to 600 p.s.f. For higher pressures, a tight board backing is necessary.

Presdwood and plywood thinner than ⅝ in. require tight backing for architectural concrete work. If sheathing boards, spaced some distance apart, or studs alone are used to receive the thin plywood or Presdwood, an objectionable impression of backing will show in the finished concrete surface as illustrated by Fig. 8.

Fig. 8

Tables 9 and 10, showing the spacing of studs or sheathing boards, are included for both plywood and Presdwood; however, the latter should be used only for the design of structural concrete forms and for forms used in an inconspicuous place where the impression of the backing lumber in the finish is not objectionable. It should be noted that wherever a Presdwood lining is used over a partial backing, each sheathing board must carry the load from center to center of boards. Unless designed for this load, a failure may result or too great deflection will occur.

Just as with ordinary sheathing lumber, the spacing of studs with plywood or Presdwood sheathing is

*Tables for rough lumber and lumber *S4S* are included, making it possible to interpolate with sufficient accuracy for lumber surfaced in any way that may be used on the job.

determined by deflection. For the loads and spacings shown in Tables 9 and 10, the deflections will be less than $l/270$. Except for forms where the concrete pressure cannot exceed 300 p.s.f., the spacing of studs with plywood sheathing of any thickness should not exceed 20 in. and a 16-in. spacing is preferable because of the possibility of somewhat greater pressure than may be anticipated.

In the range of practical pressures, the spacing of studs supporting ⅝ or ¾-in. plywood being approximately the same, it is practical to use a single maximum spacing of wales with both thicknesses of plywood. The wale-spacing is of course dependent upon the size of studs as shown in Table 11. To prevent leakage that might result from irregularities in the studs and from deflection, it is advisable around openings not to space the wales farther apart than 27 in., regardless of theoretical requirements. The wale-spacing for Presdwood-lined forms will be the same as for ordinary lumber and can be taken from Tables 5 and 6.

Use of Tables

In the design of forms by means of the tables, first obtain from Fig. 2 the maximum pressure p.s.f. exerted by the concrete, depending upon the rate at which the concrete is placed and the temperature. If ordinary lumber is to be used as sheathing, enter Table 3 or 4, depending upon whether rough boards or boards *S4S* are to be used. Under the pressure and opposite the nominal thickness of the sheathing, read the spacing of studs.

Having obtained the stud-spacing, enter Table 5 or 6, depending on whether the studs are rough or dressed, and read the spacing of wales under the pressure and for the size studs to be used. Note that the spacing of wales is affected by the thickness of sheathing.

The spacing of ties can now be obtained from Table 7 or 8 by entering the table with spacing of studs and wales, and reading the tie-spacing under the pressure of the concrete. It will be sufficiently accurate to enter the table under the nearest tabulated pressure. With the spacing of the ties and wales determined, the size ties, if pencil rods are used, can be obtained from Fig. 9 by entering the chart at the left with the spacing of wales; follow horizontally to the right to an intersection with the inclined line representing the spacing of ties; from this intersection, follow vertically up or down to an intersection with the horizontal line representing the pressure of the concrete and read the size of the tie required. The size tie will be that indicated by the curved line above and to the right of the last point of intersection mentioned. If a size greater than ⅝-in. rod is necessary for the wale and tie-spacing already determined, one or the other should be reduced because of the difficulty of pulling the large diameter rods.

Problem 4—Design a wall form 12 ft. high using lumber which is all *S4S*, if the concrete is placed at the rate of 4 ft. per hour at a temperature of 70°.

Step 1. From Fig. 2a, the maximum pressure for which the form must be designed is 530 p.s.f.

Step 2. Enter Table 4 using 1-in. nominal sheathing and find by interpolation that the stud-spacing is

$$22 - 3 \times \frac{130}{200} = 20.05 \text{ in. Say 20 in.}$$

Step 3. Assuming 2x4 studs, enter Table 6 in the group under the thickness of sheathing used and opposite the size of studs, read the spacing of wales under the pressure. Interpolating, the wale-spacing is

$$26 - 6 \times \frac{130}{200} = 22.1 \text{ in. Say 22 in.}$$

Step 4. Assuming double 2x6 wales, enter Table 8 with a stud-spacing of 20 in. and a wale-spacing of 22 in. Since these values do not appear in the table, it is necessary to make a double interpolation between the nearest tabular values, namely stud-spacings of 18 and 21 in. and wale-spacings of 21 and 24 in. Although the pressure is actually 530 p.s.f., enter the table under the nearest tabulated pressure, 600 p.s.f. By interpolation, the tie-spacing is

$$(36 - 6 \times 2/3) - [(36 - 6 \times 2/3) - (28 - 4 \times 2/3)]1/3 = 29.8 \text{ in. Say 30 in.}$$

Step 5. Having the maximum tie-spacing, enter Fig. 9 with the wale-spacing; follow horizontally to the right to an intersection with the inclined line representing the spacing of ties; from this intersection, go vertically up or down to an intersection with the horizontal line representing pressure of the concrete, and read the size of tie required. In this case, a ⅜-in. round tie will be sufficient. This completes the design.

TABLE No. 3—Maximum Spacing of Studs for Rough Sheathing

Modulus of Elasticity—1,600,000 Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ Horizontal Shear— 200 p.s.i.

Nominal Thickness of Sheathing	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
	400	600	800	1000	1200	1400	1600
1- in.	27	24	22	20	18	17	16
1¼-in.	34	30	28	26	24	22	20
1½-in.	42	36	33	30	28	26	24
2- in.	54	48	45	42	39	36	33

TABLE No. 4—Maximum Spacing of Studs for Sheathing *S4S*

Modulus of Elasticity—1,600,000 Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ Horizontal Shear— 200 p.s.i.

Nominal Thickness of Sheathing	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
	400	600	800	1000	1200	1400	1600
1- in.	22	19	17	16	14	13	12
1¼-in.	30	27	24	22	20	18	16
1½-in.	36	33	30	27	24	22	20
2- in.	45	40	36	33	30	28	26

TABLE No. 5—Maximum Spacing of Wales for Rough Studs With Rough Sheathing

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

Nominal Sizes of Studs	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
	400	600	800	1000	1200	1400	1600
1" Nominal Sheathing—Rough							
2x4	28	21	18	16			
2x6	42	32	27	24	21	18	
2x8	56	42	36	31	29	27	24
3x6	60	48	40	36	33	30	27
3x8		60	54	45	42	39	36
1¼" Nominal Sheathing—Rough							
2x4	22	17					
2x6	34	26	21	19			
2x8	45	35	27	24	21		
3x6	51	39	31	27	24	22	22
3x8	60	52	42	36	32	30	29
1½" Nominal Sheathing—Rough							
2x4	18						
2x6	28	21	18				
2x8	36	29	23	20			
3x6	41	32	27	23			
3x8	54	42	35	30	27	24	
2" Nominal Sheathing—Rough							
2x4							
2x6	21	16					
2x8	29	21	16				
3x6	32	24	18				
3x8	42	32	26	22	20		

TABLE No. 6—Maximum Spacing of Wales for Studs *S4S* with Sheathing *S4S*

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

Nominal Sizes of Studs	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
	400	600	800	1000	1200	1400	1600
1" Nominal Sheathing *S4S*							
2x4	26	20					
2x6	40	31	25	22	21		
2x8	54	40	34	29	28	26	24
3x6	60	50	41	36	34	32	30
3x8		60	55	48	45	42	40
1¼" Nominal Sheathing *S4S*							
2x4	19						
2x6	29	22	18				
2x8	38	29	23	21			
3x6	47	35	29	26	23	21	
3x8	60	47	40	35	32	30	29
1½" Nominal Sheathing *S4S*							
2x6	25	18					
2x8	32	23	19	16			
3x6	39	29	23	21	19		
3x8	52	38	31	28	26	24	23
2" Nominal Sheathing *S4S*							
2x6	19						
2x8	26	19					
3x6	31	23	19				
3x8	42	31	26	23	21	19	18

TABLE No. 7—Maximum Spacing of Ties for Double Wales—Rough Lumber

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

2—2x4 Wales—Rough

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
		400	600	800	1000	1200	1400	1600
12	15	60	54	38	28	20		
	18	60	44	30	20			
	21	56	36	24				
	24	52	30					
	30	38	20					
	36	30						
	42	24						
15	15	60	52	34	24			
	18	60	40	26				
	21	56	32	20				
	24	48	26					
	30	34						
	36	26						
	42	20						
18	15	60	54	32				
	18	60	38	22				
	21	54	30					
	24	44	22					
	30	32						
	36	22						

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

2—2x4 Wales—Rough (continued)

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
		400	600	800	1000	1200	1400	1600
21	15	60	46	26				
	18	58	32	22				
	21	52	24					
	24	42						
	30	26						
	36	22						
24	15	60	42	26				
	18	58	30					
	21	50	24					
	24	36						
	30	26						
30	15	60	34					
	18	54						
	21	38						
	24	32						
36	15	60	34					
	18	44						
	21	36						
42	15	54						
	18	42						
48	15	52						

(*Table No. 7 continued on following page.*)

TABLE No. 7—Continued

2—2x6 Wales—Rough

Spacing of Studs	Spacing of Wales	400	600	800	1000	1200	1400	1600
		PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
12	15	60	60	60	50	40	32	26
	18	60	60	52	40	30	24	
	21	60	58	42	32	24		
	24	60	52	36	26			
	30	60	40	26				
	36	52	30					
	42	42	24					
	48	36						
	54	30						
	60	26						
15	15	60	60	60	44	34	28	20
	18	60	60	48	34	26		
	21	60	58	38	28			
	24	60	48	32	20			
	30	60	34	20				
	36	48	24					
	42	38						
	48	32						
	54	26						
	60	20						
18	15	60	60	58	42	30	22	20
	18	60	58	44	30	22		
	21	60	54	36	22			
	24	60	44	26	20			
	30	58	30	20				
	36	44	22					
	42	36						
	48	26						
	54	22						
	60	20						
21	15	60	60	54	40	26	22	
	18	60	60	44	26	22		
	21	60	50	30	22			
	24	60	42	24				
	30	54	26					
	36	42	22					
	42	30						
	48	24						
	54	22						
24	15	60	60	52	32	26		
	18	60	58	36	26			
	21	60	50	28				
	24	60	36	24				
	30	52	26					
	36	34						
	42	28						
	48	24						
30	15	60	60	42	30			
	18	60	52	32				
	21	60	38					
	24	60	32					
	30	42						
	36	32						
36	15	60	60	38				
	18	60	44					
	21	60	36					
	24	54						
	30	38						
42	15	60	54					
	18	60	42					
	21	60						
	24	48						
48	15	60	50					
	18	60						
	21	56						
	24	48						
54	15	60						
	18	60						
	21	54						

2—2x8 Wales—Rough

Spacing of Studs	Spacing of Wales	400	600	800	1000	1200	1400	1600
		PRESSURE OF CONCRETE—POUNDS PER SQ. FT.						
12	15	60	60	60	60	54	46	38
	18	60	60	60	54	44	36	28
	21	60	60	60	46	36	26	22
	24	60	60	50	38	28	22	
	30	60	54	38	26	20		
	36	60	44	28	20			
	42	60	36	22				
	48	50	28					
	54	44	24					
	60	38	20					
15	15	60	60	60	58	50	42	34
	18	60	60	60	50	40	32	26
	21	60	60	56	42	32	24	
	24	60	60	46	34	26		
	30	60	50	34	24			
	36	60	40	26				
	42	56	32					
	48	46	26					
	54	40						
	60	34						
18	15	60	60	60	60	48	40	30
	18	60	60	60	48	38	28	22
	21	60	60	54	40	28	20	
	24	60	60	44	30	22		
	30	60	48	30	20			
	36	60	38	22				
	42	54	28					
	48	44	22					
	54	38						
	60	30						
21	15	60	60	60	60	46	36	26
	18	60	60	60	46	32	24	
	21	60	60	50	34	24		
	24	60	60	42	26			
	30	60	46	26				
	36	60	32					
	42	50	24					
	48	42						
	54	32						
	60	26						
24	15	60	60	60	56	40	32	26
	18	60	60	60	40	30	24	
	21	60	60	48	30	24		
	24	60	60	36	26			
	30	60	40	26				
	36	60	30					
	42	48	24					
	48	36						
	54	30						
	60	26						
30	15	60	60	60	46	34		
	18	60	60	50	34			
	21	60	60	38				
	24	60	50	32				
	30	60	34					
	36	50						
	42	38						
	48	32						
36	15	60	60	60	42			
	18	60	60	44				
	21	60	58	36				
	24	60	44					
	30	60						
	36	44						
	42	36						
42	15	60	60	54				
	18	60	60	42				
	21	60	50					
	24	60	42					
	30	54						
	36	42						
48	15	60	60	52				
	18	60	58					
	21	60	48					
	24	60						
	30	52						
54	15	60	60					
	18	60	56					
	21	60						
	24	60						

TABLE No. 7—Continued

2—3x6 Wales—Rough

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	60	60	60	60	60	52	48
	18	60	60	60	60	52	42	36
	21	60	60	60	52	42	34	28
	24	60	60	60	44	36	28	
	30	60	60	52	32	26		
	36	60	52	36	26			
	42	60	42	28				
	48	60	36	24				
	54	52	30					
	60	48	26					
15	15	60	60	60	60	60	50	42
	18	60	60	60	60	48	38	32
	21	60	60	60	50	38	30	24
	24	60	60	56	42	32	24	
	30	60	60	42	30	20		
	36	60	48	32	20			
	42	60	38	24				
	48	56	32					
	54	48	26					
	60	42	20					
18	15	60	60	60	60	58	46	38
	18	60	60	60	58	44	36	26
	21	60	60	60	46	36	26	
	24	60	60	54	38	26		
	30	60	58	38	26			
	36	60	44	26				
	42	60	36	20				
	48	54	26					
	54	44	22					
	60	38						
21	15	60	60	60	60	54	44	32
	18	60	60	60	54	42	30	24
	21	60	60	58	44	30	24	
	24	60	60	48	32	24		
	30	60	54	32	24			
	36	60	42	24				
	42	58	30					
	48	48	24					
	54	42	20					
	60	32						
24	15	60	60	60	60	52	38	30
	18	60	60	60	52	36	28	24
	21	60	60	56	38	28		
	24	60	60	48	30	24		
	30	60	52	30				
	36	60	36	24				
	42	56	28					
	48	48	24					
	54	36						
	60	30						
30	15	60	60	60	60	42	34	
	18	60	60	60	42	32		
	21	60	60	48	34			
	24	60	60	38				
	30	60	42					
	36	60	32					
	42	48						
	48	38						
	54	32						
36	15	60	60	60	50	38		
	18	60	60	54	38			
	21	60	60	42				
	24	60	54	36				
	30	60	38					
	36	54						
	42	42						
	48	36						
42	15	60	60	60	46			
	18	60	60	48				
	21	60	60					
	24	60	48					
	30	60						
	36	48						
48	15	60	60	60				
	18	60	60	48				
	21	60	56					
	24	60	48					
	30	60						
	36	48						
54	15	60	60	58				
	18	60	60					
	21	60	54					
	24	60						
	30	58						

2—3x8 Wales—Rough

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	60	60	60	60	60	60	60
	18	60	60	60	60	60	60	50
	21	60	60	60	60	60	50	42
	24	60	60	60	60	50	42	36
	30	60	60	60	48	38	30	26
	36	60	60	50	38	28	24	
	42	60	60	42	30	24		
	48	60	50	36	26			
	54	60	44	28	20			
	60	60	38	26				
15	15	60	60	60	60	60	60	60
	18	60	60	60	60	60	58	48
	21	60	60	60	60	58	46	38
	24	60	60	60	60	48	38	32
	30	60	60	60	46	34	28	20
	36	60	60	48	34	26		
	42	60	58	38	28			
	48	60	48	32	20			
	54	60	40	26				
	60	60	34	20				
18	15	60	60	60	60	60	60	54
	18	60	60	60	60	60	52	42
	21	60	60	60	60	52	40	34
	24	60	60	60	54	42	34	26
	30	60	60	54	40	30	22	
	36	60	60	42	30	22		
	42	60	52	34	22			
	48	60	42	26				
	54	60	38	22				
	60	54	30					
21	15	60	60	60	60	60	60	54
	18	60	60	60	60	60	50	42
	21	60	60	60	60	50	42	30
	24	60	60	60	54	42	30	24
	30	60	60	54	40	28	22	
	36	60	60	42	28	22		
	42	60	50	30	22			
	48	60	42	24				
	54	60	32	22				
	60	54	28					
24	15	60	60	60	60	60	60	52
	18	60	60	60	60	60	50	36
	21	60	60	60	60	50	34	28
	24	60	60	60	52	36	28	24
	30	60	60	52	34	26		
	36	60	60	36	26			
	42	60	50	28				
	48	60	36					
	54	60	30					
	60	52	26					
30	15	60	60	60	60	60	56	42
	18	60	60	60	60	52	38	
	21	60	60	60	56	38		
	24	60	60	60	42			
	30	60	60	42	30			
	36	60	52	32				
	42	60	38					
	48	60	32					
	54	52						
	60	42						
36	15	60	60	60	60	60	48	38
	18	60	60	60	60	44	36	
	21	60	60	60	46	36		
	24	60	60	56	38			
	30	60	60	38				
	36	60	44					
	42	60	36					
	48	56						
	54	46						
	60	38						
42	15	60	60	60	60	54	44	
	18	60	60	60	54	42		
	21	60	60	60	44			
	24	60	60	48				
	30	60	54					
	36	60	42					
	42	60						
	48	48						
	54	42						
48	15	60	60	60	60	52		
	18	60	60	60	52			
	21	60	60	56				
	24	60	60	48				
	30	60	52					
	36	60						
	42	56						
	48	48						

TABLE No. 8—Maximum Spacing of Ties for Double Wales—Lumber *S4S*

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

2—2x4 Wales—*S4S*

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	54	38	26				
	18	50	28					
	21	40	22					
	24	36						
	30	26						
15	15	56	34	20				
	18	46	24					
	21	36						
	24	32						
	30	20						
18	15	52	30					
	18	42	20					
	21	34						
	24	26						
21	15	50	26					
	18	40						
	21	28						
	24	22						
24	15	52	24					
	18	34						
	21	26						
30	15	40						
	18	30						
36	15	36						

2—2x6 Wales—*S4S*

Spacing of Studs	Spacing of Wales	400	600	800	1000	1200	1400	1600
12	15	60	60	44	34	26		
	18	60	52	36	26			
	21	60	42	28				
	24	60	36	24				
	30	44	26					
	36	36						
	42	28						
	48	24						
15	15	60	58	42	30	22		
	18	60	48	32	22			
	21	60	40	24				
	24	56	32					
	30	42	22					
	36	32						
	42	24						
18	15	60	58	38	26			
	18	60	44	28				
	21	60	36	20				
	24	54	28					
	30	38						
	36	28						
	42	20						
21	15	60	56	34	24			
	18	60	42	24				
	21	58	30					
	24	48	24					
	30	34						
	36	24						
24	15	60	50	30				
	18	60	36	24				
	21	55	28					
	24	48	24					
	30	30						
	36	24						
30	15	60	42					
	18	60	32					
	21	48						
	24	38						
36	15	60	40					
	18	54						
	21	42						
	24	36						
42	15	60						
	18	50						
48	15	60						
	18	48						
54	15	60						

Modulus of Elasticity—1,600,000 | Extreme Fiber Stress—1800 p.s.i.
Allowable Deflection— $l/270$ | Horizontal Shear— 200 p.s.i.

2—2x8 Wales—*S4S*

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	60	60	60	50	40	32	26
	18	60	60	52	40	30	24	
	21	60	58	42	32	24		
	24	60	52	36	26			
	30	60	40	26				
	36	52	30					
	42	42	24					
	48	36						
	54	30						
	60	26						
15	15	60	60	60	46	36	28	20
	18	60	60	50	36	26		
	21	60	58	38	28			
	24	60	50	32	20			
	30	60	36	20				
	36	50	26					
	42	38						
	48	32						
	54	26						
	60	20						
18	15	60	60	60	42	32	24	
	18	60	60	44	32	22		
	21	60	54	36	24			
	24	60	44	28				
	30	60	32					
	36	44	22					
	42	36						
	48	28						
	54	22						
21	15	60	60	54	40	28	22	
	18	60	60	42	28	22		
	21	60	50	30	22			
	24	60	42	24				
	30	54	28					
	36	42	22					
	42	30						
	48	24						
	54	22						
24	15	60	60	52	34	26		
	18	60	60	36	26			
	21	60	50	28				
	24	60	36	24				
	30	52	26					
	36	36						
	42	28						
	48	24						
30	15	60	60	42	32			
	18	60	54	32				
	21	60	40					
	24	60	32					
	30	42						
	36	32						
36	15	60	60	38				
	18	60	44					
	21	60	36					
	24	54						
	30	38						
42	15	60	56					
	18	60	42					
	21	60						
	24	50						
48	15	60	52					
	18	60						
	21	56						
	24	48						
54	15	60						
	18	60						
	21	54						

TABLE No. 8—Continued

2—3x6 Wales—*S4S*

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	60	60	60	60	50	42	34
	18	60	60	60	50	40	32	26
	21	60	60	54	42	32	26	20
	24	60	60	46	34	26	20	
	30	60	50	34	24			
	36	60	40	26				
	42	54	32	20				
	48	46	26					
	54	40	22					
	60	34						
15	15	60	60	60	58	48	36	30
	18	60	60	60	48	36	28	22
	21	60	60	50	36	28	20	
	24	60	60	44	30	22		
	30	60	48	30				
	36	60	36	22				
	42	50	28					
	48	44	22					
	54	36						
	60	30						
18	15	60	60	60	56	42	36	26
	18	60	60	58	42	32	24	
	21	60	60	48	36	24		
	24	60	58	40	26			
	30	60	42	26				
	36	58	32					
	42	48	24					
	48	40						
	54	32						
	60	26						
21	15	60	60	60	52	40	28	24
	18	60	60	56	40	28	22	
	21	60	60	44	28	22		
	24	60	56	34	24			
	30	60	40	24				
	36	56	28					
	42	44	22					
	48	34						
	54	28						
	60	24						
24	15	60	60	60	50	34	28	
	18	60	60	52	34	26		
	21	60	60	40	28			
	24	60	52	30				
	30	60	34					
	36	52	26					
	42	40						
	48	30						
	54	26						
30	15	60	60	60	40	32		
	18	60	60	44	32			
	21	60	60	34				
	24	60	44					
	30	60	32					
	36	44						
	42	34						
36	15	60	60	52	38			
	18	60	60	40				
	21	60	48					
	24	60	40					
	30	52						
	36	40						
42	15	60	60	48				
	18	60	56					
	21	60	46					
	24	60						
	30	48						
48	15	60	60					
	18	60	60					
	21	60						
	24	60						
54	15	60	60					
	18	60	60					
	21	60						
	24	60						

2—3x8 Wales—*S4S*

Spacing of Studs	Spacing of Wales	PRESSURE OF CONCRETE—POUNDS PER SQ. FT. 400	600	800	1000	1200	1400	1600
12	15	60	60	60	60	60	58	50
	18	60	60	60	60	58	48	40
	21	60	60	60	58	48	38	34
	24	60	60	60	50	40	34	28
	30	60	60	50	38	30	24	
	36	60	58	40	30	22		
	42	60	48	32	24			
	48	60	40	28				
	54	58	36	22				
	60	50	30					
15	15	60	60	60	60	60	56	46
	18	60	60	60	60	54	44	36
	21	60	60	60	56	44	34	30
	24	60	60	60	46	36	30	22
	30	60	60	46	34	24		
	36	60	54	36	24			
	42	60	44	30				
	48	60	36	22				
	54	54	32					
	60	46	24					
18	15	60	60	60	60	60	54	42
	18	60	60	60	60	50	40	32
	21	60	60	60	54	40	30	24
	24	60	60	60	42	32	24	
	30	60	60	42	30	22		
	36	60	50	32	22			
	42	60	40	24				
	48	60	32	20				
	54	50	26					
	60	42	22					
21	15	60	60	60	60	60	48	42
	18	60	60	60	60	46	36	28
	21	60	60	60	48	36	28	22
	24	60	60	56	42	28	22	
	30	60	60	42	26			
	36	60	46	28				
	42	60	36	22				
	48	56	28					
	54	46	24					
	60	42						
24	15	60	60	60	60	58	48	34
	18	60	60	60	58	44	32	26
	21	60	60	60	48	32	26	
	24	60	60	52	34	26		
	30	60	58	34	24			
	36	60	44	26				
	42	60	32					
	48	52	26					
	54	44						
	60	34						
30	15	60	60	60	60	50	38	32
	18	60	60	60	50	36	30	
	21	60	60	60	38	30		
	24	60	60	44	32			
	30	60	50	32				
	36	60	36					
	42	60	30					
	48	44						
	54	36						
	60	32						
36	15	60	60	60	58	42	36	
	18	60	60	60	42			
	21	60	60	48	36			
	24	60	60					
	30	60	42					
	36	60						
	42	48						
	48	40						
42	15	60	60	60	54	42		
	18	60	60	56	42			
	21	60	60	44				
	24	60	56					
	30	60	42					
	36	56						
	42	44						
48	15	60	60	60	50			
	18	60	60	52				
	21	60	60					
	24	60	52					
	30	60						
	36	52						
54	15	60	60	60				
	18	60	60					
	21	60	60					
	24	60						
	30	60						

TABLE No. 9—Maximum Allowable Load in Pounds per Sq. Ft. on 5-Ply Douglas Fir Plywood for Deflections not exceeding $\frac{\text{Span}}{270}$

Thickness of Plywood	CLEAR SPAN			
	12-in.	16-in.	20-in.	24-in.
⅝-in.	600	430	280	185
¾-in.	650	500	360	260

TABLE No. 10—Maximum Allowable Load in Pounds per Sq. Ft. on Tempered Presdwood for Deflections Not Exceeding $\frac{\text{Span}}{270}$

Thickness of Presdwood	CLEAR SPAN			
	4-in.	6-in.	8-in.	10-in.
¼-in.	500	350	215	130
5/16-in.	900	675	400	240

TABLE No. 11—Maximum Spacing of Wales for Rough and Dressed Studs with ⅝ or ¾-in. 5-Ply Plywood Sheathing

Nominal Size of Studs Rough	Spacing of Wales Inches	Nominal Size of Studs *S4S*	Spacing of Wales Inches
2x4	38	2x4	28
2x6	58	2x6	44
2x8	60	2x8	60
3x6	60	3x6	60
3x8	60	3x8	60

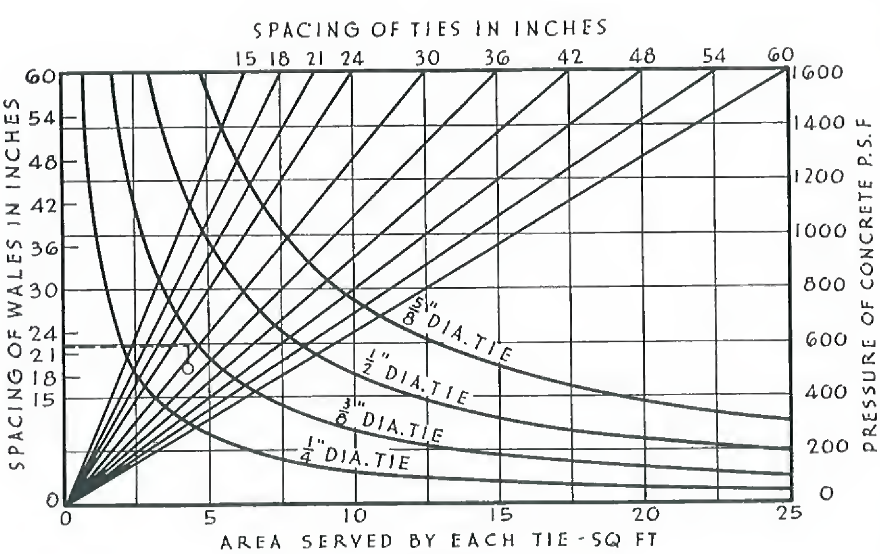


Fig. 9

SECTION III

MILL FOR MAKING FORMS

The cost of forms is an important part of the cost of an architectural concrete job, and the efficiency of the mill for making forms materially affects their cost. The larger the job, and therefore the greater the amount of equipment necessary in the mill, the more influence the layout will have on the cost. Obviously, the mill for a small job consisting of little more than a saw and a bench will have little effect on the final cost, but a large mill should be planned carefully.

Definite rules for the location, size and equipment of a form mill cannot be given, because they are dependent upon the conditions of each individual job. However, consideration of a few of the general requirements which apply to practically every large job will aid in the design of the plant for a specific project.

The mill should be located as close to the building as possible, with due consideration for the necessity of allowing space for the storage of finished forms. It is also advisable to place the material hoist and concrete plant in the most central position and immediately adjacent to the building. This is important because of the labor required for transporting the concrete into the building, if the plant is too far removed, as compared with the work involved in handling forms. The space available and the location of the building site in relation to the street or streets will influence the mill layout. If at all possible, the mill should be located so that a progressive operation can be followed from the place where the lumber is received to the place where the finished forms are delivered to the erection crew. Similar considerations affect the interior layout of the mill.

A storage space for incoming material from the lumber yard will be necessary. The space required will depend entirely on the size of job and whether materials can be obtained on short notice by truck from a local yard or must be stored in carloads or larger lots. The receiving yard should be located convenient to the rip and cut-off saws, in order to require the least possible handling of material. When space permits, the receiving yard should also be convenient to the bench carpenters fabricating panels, because much of the material will not have to go through the mill to prepare it for use. Material as it is received should be piled according to sizes, so that no time will be lost in searching for pieces of a desired size. On especially large jobs where there are many piles of material, some contractors have found it advisable to label each stock pile in the receiving yard and

the piles of lumber that are prepared for the bench carpenters, with signs showing the size pieces in the different piles. This enables the stock man to make a quick selection of the material wanted and avoids the waste of cutting pieces uneconomically.

Adjacent to the mill and as close as possible to the material hoist, a space should be provided for storage of the completed panels or partially assembled forms that are ready for erection on the job. This space should be convenient to the benches within the mill or just outside the mill where the panels are built.

A well-equipped mill for an average job will require a cut-off saw and rip saw or one that will perform both operations. Usually, a swing type cut-off saw is best where separate saws are used. The saws should be capable of handling at least 2-in. material and should be adjustable to cut or rip at any angle or bevel. This is necessary because of the odd shapes that may be required. If there is to be considerable ornament, a band saw will reduce the amount of handwork. A portable electric saw for use by the bench carpenters will save considerable time in fabricating panels. Adjustable benches made by laying planks on saw horses are better than permanent benches, because of the difficulty of working around panels of varying sizes when the bench is made large enough to accommodate the largest panels.

A stock rack for rippings and moldings is a useful piece of equipment to reduce breakage and to keep various sizes and shapes of pieces separated. By providing a stock rack, usually consisting of 15 to 20 compartments 12x15 in. in cross-section and 10 to 12 ft. long, the mill man can tell when certain sizes run short, avoiding delay for the bench carpenters.

If the job is large enough to warrant them, a planer and boring machine are useful. Emery wheels and other tool sharpening equipment are always desirable.

A typical mill layout with necessary storage facilities is shown in Fig. 10. It is desirable to provide a roof for the mill to protect the equipment and the men, but the sides should be as open as possible to facilitate handling material. The material to be ripped is stored where it can be fed directly onto the rip saw table. From the haul-off table of the rip saw, the material can be placed in the storage rack inside the mill or in the stock piles outside, ready for the bench carpenters. The saw in this layout is a combination rip and cut-off type. It is served by a table at the side closest to the storage piles to facilitate handling material to the saw.

The position shown for the band saw is convenient because material can be passed from the cut-off or rip saw to the band saw operator, and thence to the storage rack or directly to the bench carpenters.

Cramped space should be avoided but unnecessary room is likewise undesirable. A clear space of 4 or 5 ft. around the saws with their haul-off and feed tables is about right. There should also be 3 or 4-ft. aisles between benches, so carpenters do not interfere with each other.

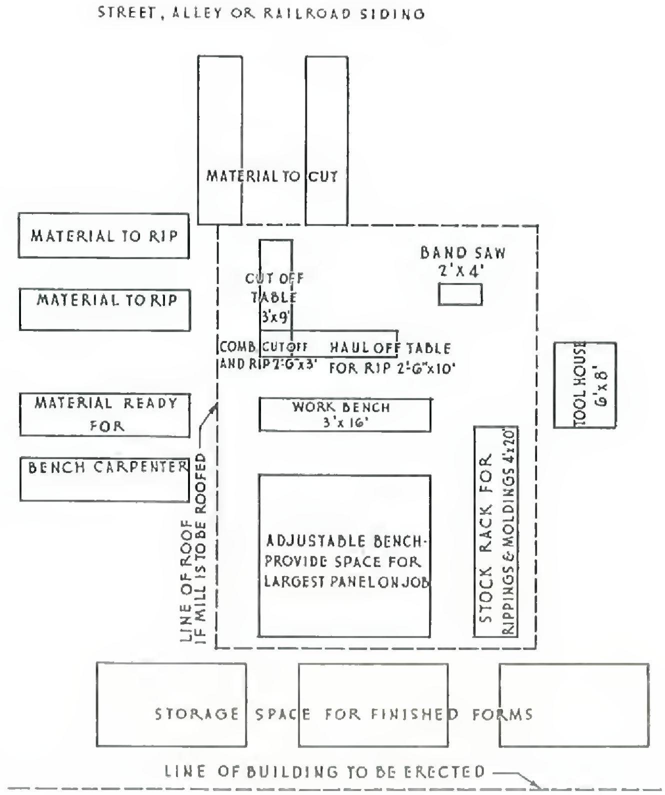


Fig. 10

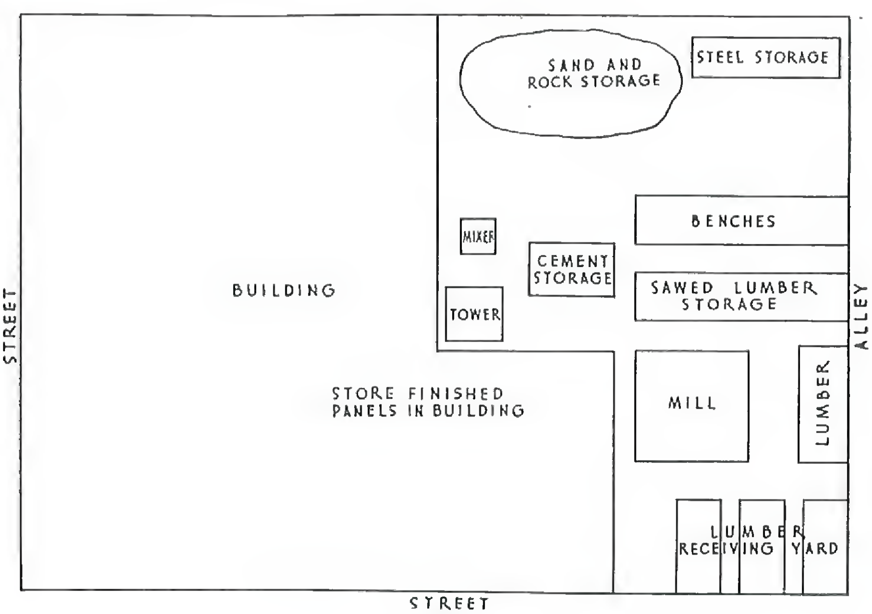


Fig. 11

A mill with storage space such as shown in Fig. 10 can be used only where there is ample room in a vacant lot adjacent to the building site, or a future parking space on the lot.

The assembly benches are frequently just outside the mill, as shown in Fig. 11. This layout has the advantage of requiring much less space in the mill, and usually allows more room around the benches. A disadvantage is that inclement weather interferes with the work on the benches, whereas, if under cover, work could proceed on panels in preparation for the erection crew when outside work is resumed. If this is done, a few extra men in the erection crew can often make up for lost time.

Where a building occupies the entire site and there is no vacant land adjoining as in a downtown area, the mill must often be strung out along the building site on the sidewalk. This may complicate the mill layout slightly, but observance of the general requirements of such plants will result in an efficient arrangement.

Fig. 12 illustrates a "sidewalk" mill layout. A space 10 to 12 ft. wide is required, of sufficient length to accommodate the equipment. The mill must be placed next to the street, to allow delivery of materials without interfering with pedestrians. Pedestrians are provided with a walkway, covered for protection, between the mill and the building. A light fence along the street side is necessary to protect the workmen from passing vehicles.

In this layout, the operations begin at the two ends and proceed toward the center where the assembly benches are located. Material to be ripped is delivered at one end, and material for band saw and cut-off saw is delivered at the other. After the lumber has been prepared for use, if not needed immediately it is stored in racks made of brackets attached to the wall, or under the benches if space is limited. When the material has been assembled by the bench carpenters, the form panels are delivered directly to the building through a large central gate.

If the building is one of several stories, it is often desirable to move the mill into the building, particularly if working and storage space outside is limited. Some adjustment and rearrangement of equipment for an inside layout may be necessary, but the same principle of progressive fabrication of the forms should be followed.

SECTION IV

ERECTION ACCESSORIES

The care exercised in the selection and proper use of erection accessories is reflected in the quality of the work and in the cost. There are many patented devices on the market having merit for some classes of work, but all should be carefully studied before being used on an architectural concrete job, because of the possible effect on appearance.

Nails

Nails are an essential, but their improper use can add appreciably to the cost of the work and may even result in damage to the concrete. Forms must be substantial and the component parts must be securely held together, but the use of too large or too many nails should be avoided; labor required for fabrication, erection and stripping will thereby be saved and much greater re-use of the lumber can be made, as it will not split and break so frequently when stripping.

Fig. 13—In a rough texture the impression of the heads of common nails is not objectionable but would mar a smoother surface.

Box nails are best for attaching sheathing to studs for built-in-place forms, because the shank is thinner than that of *common* nails and will pull loose from the studs more readily. The size will depend upon the thickness of sheathing. For nominal 1-in. sheathing or ⅝-in. and thicker plywood 6*d* nails are recommended.

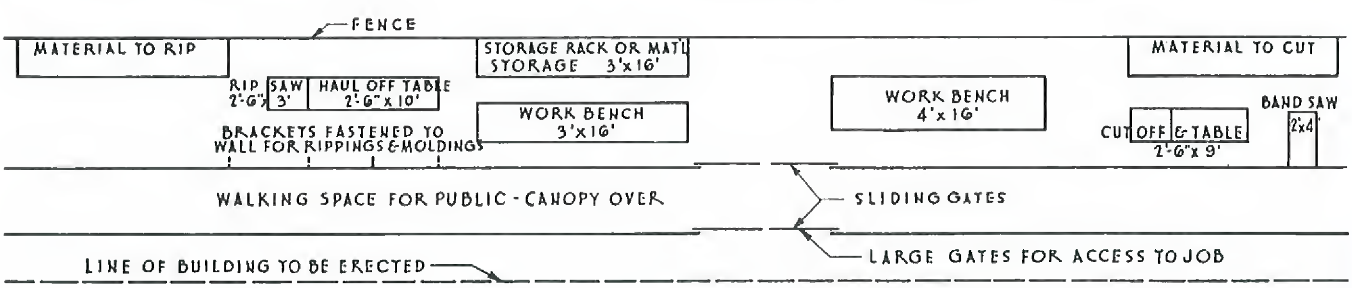


Fig. 12

Common nails of this size are better for panel forms because they must stand considerable racking and abuse.

Presdwood and thin plywood used as a form liner over sheathing should be attached with small nails having thin flat heads. *Three-penny blue shingle* nails are generally considered best for this purpose. The heads of these nails leave but a very faint impression in the concrete, while the small diameter shank pulls out of the sheathing easily without pulling the head through the lining material, which would make it unsatisfactory for further use unless the edges were trimmed.

Common nails should be used sparingly, except in the fabrication of forms to be re-used several times without alteration. Their heads make a more noticeable impression in the concrete when the nails are in a contact surface than do box nails, while the holding power of common nails makes them difficult to remove. For nailing kickers, blocks, braces, reinforcing for wales, and similar pieces that require nails of considerable holding power and yet must be removed readily, use *double-headed* nails.

Fig. 14—Double-headed nails were used in assembling this form so the nails could be pulled easily and the form stripped without damaging the sharp edges of the reveal.

Double-headed nails can be pulled easily and quickly with a claw hammer or stripping bar without bruising or otherwise damaging the lumber. The size will depend upon the material to be nailed and the load to be carried.

Bolts

Bolts, except as ties, are not so frequently used in the erection of building forms as for forms for heavier construction where timbers too large to be fastened together by nailing are required. A bolt made of a rod threaded at both ends and provided with nuts is sometimes preferred to a standard bolt. When a bolt of this kind is used as an anchor at a construction joint to hold the form above tightly against the hardened concrete, the shank of the bolt can be unscrewed, thereby losing only the nut, and leaving no metal near the surface to corrode. To facilitate removal, the thread on the end of the rod in the concrete should be only long enough to receive the nut. Three-eighth-inch bolts are generally used for this purpose. Further information regarding construction joints is given on pages 57 and 58.

Ties

There are a number of factors to be taken into consideration in the choice of form ties. The first cost of the ties is important but should never be a controlling factor. Possible re-use, speed and ease with which the ties can be placed and removed; adaptability to built-in-place and panel forms; positiveness of action; and most important of all, the effect on the appearance of the finished job, should be carefully considered.

Because the first cost was little, wire was at one time the most common form tie. It was passed through the forms and twisted about the studs, or otherwise drawn taut. But at best, wire ties were never satisfactory because the wire would stretch or bite into the wood under pressure of the concrete, causing irregularities in alignment and wall thickness.

For architectural concrete work, wire ties have all the undesirable qualities that they have for structural work. But there are added objections—unless the wires remain straight in the wall and are held on the outside by a device so they can be pulled out of the wall after the concrete has hardened, they must be cut off. Quite a large hole is made in the concrete in order to cut the wire back far enough from the forms so it will not corrode and discolor the surface. These large holes are difficult to plug so they will not be noticeable, and because of possible shrinkage of the large plug of mortar, some moisture may reach the wire causing it to corrode and spall the concrete. There are so many objections to wire ties that they should not be used under any circumstances on an architectural concrete job.

The most satisfactory tie is one that is adjustable in length and of such type that no metal is left closer than $1\frac{1}{2}$ in. of the surface. Ties that can be completely removed from the wall or that break back the prescribed distance are acceptable. Because perfection of finish is the ultimate aim in architectural concrete, ties fitted with lugs, cones, washers and similar devices to act as spreaders are not suitable since they leave blemishes on the surface. As a rule when a tie is pulled or broken off it should not leave a hole larger than $\frac{7}{8}$ in. in diameter and a tie leaving an even smaller hole is preferred. Simplicity is always a desirable attribute in form ties. The less elaborate a tie and the fewer "gadgets" there are to handle, the quicker it can be

installed which may mean an appreciable saving on the job.

A tie consisting of a straight unthreaded pencil rod with "buttons" or clamps which are slipped over the rod and bear against the wales, as shown in Fig. 15, meets all the requirements of a simple, inexpensive

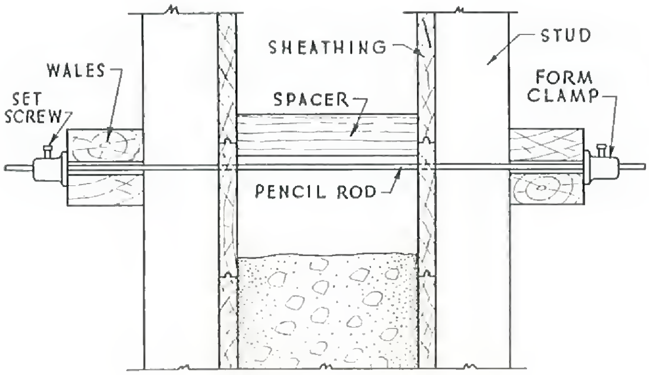


Fig. 15

and effective tie. Pencil rods of any desired size are carried in stock, making them quickly available. The rods are easily cut to the required length. The clamps grip the rod by means of a set screw which puts a crimp in the rod (Fig. 16) so it cannot slip, the holding power

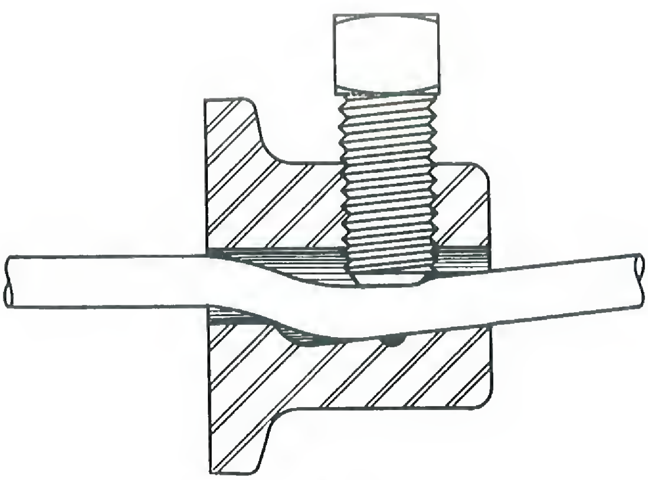


Fig. 16

of the grip being as great as the strength of the rod. The rods are often bent down to further insure against slippage, as well as for the sake of safety. A typical job installation is shown in the photograph in Fig. 17. The area of the base of the button is proportioned to give a safe bearing pressure on the wales so there will be no movement due to crushing of the timber. A tightening wrench (Fig. 18) is used to force the clamps tightly against the wales.

Only a few inches of rod are lost each time it is used, so the rod can be re-used until too short for the thinnest wall. The kink at the outer end of the rod must be

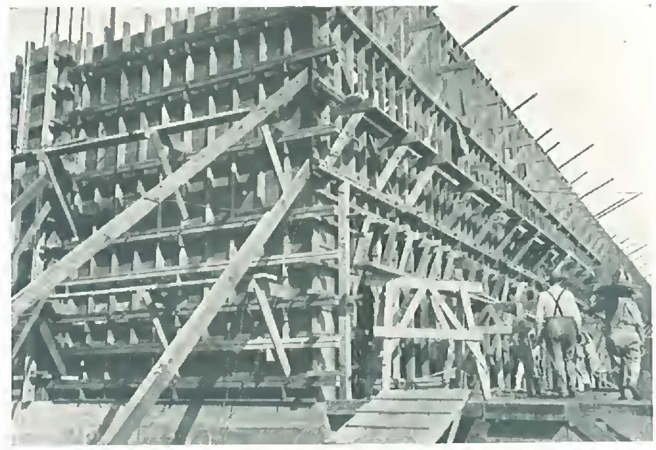
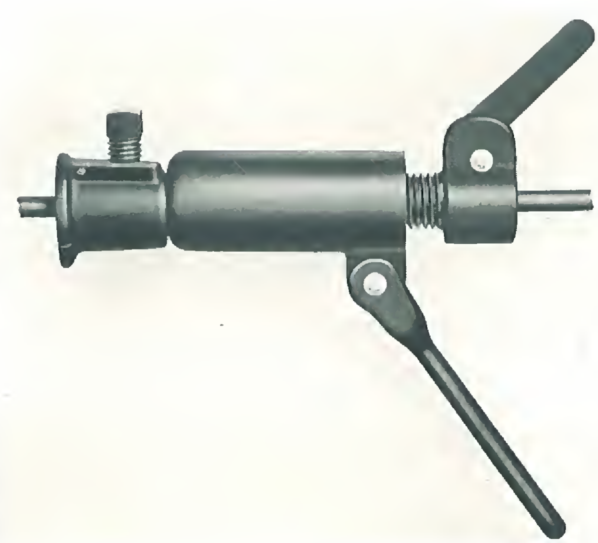


Fig. 17—A well-constructed form is illustrated. Note that tie rods have been bent down to insure against slippage and for the sake of safety. The intersections of the wales had not been blocked when the photograph was taken.

cut off in order to pull it through the wall. The rod should always be pulled toward the inside to avoid spalling the concrete on the exposed surface. A rod-puller (Fig. 19) is available which does not kink the rods and exerts a pull of sufficient force to withdraw from hardened concrete the largest tie rod normally used. The rods should be well coated with cup grease to facilitate removal and care must be used not to bend or kink the rods within the wall when tamping the concrete.

Spreaders

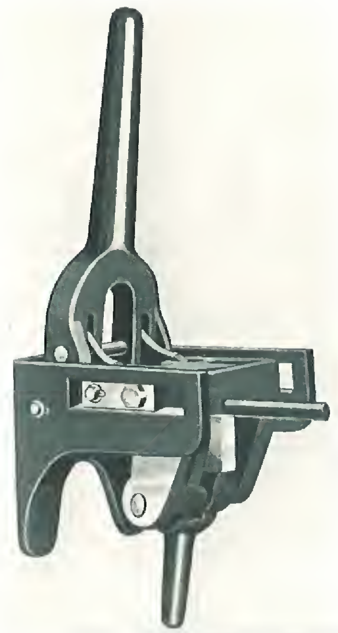
Spreaders must be provided in wall forms to prevent the sides being forced in when the tie rod clamps are tightened. There are as many types of spreaders on the market as there are clamps or ties and each has its



Courtesy Universal Form Clamp Co.

Fig. 18

merits for certain uses. The objection that applies to many ties for architectural concrete work also applies to most spreaders, namely, they leave too large a hole at the surface to be plugged. It is difficult at best to match the color and texture of the wall with the mortar used for plugs, therefore the hole to be plugged should always be as small as possible. A good solution of the problem is the use of the old-fashioned wooden spreader made of rippings of 1-in. boards. When the spreaders are removed from the forms, the only holes to be plugged are those left by the pencil rods. To be sure that none are buried, all spreaders except the top row should be removed before closing clean-out holes. The top row is removed when the concrete reaches that level.



Courtesy Universal Form Clamp Co.

Fig. 19

It is usually sufficient to place spreaders on the line of every other row of wales. If the wales are quite close together, say 15 or 18 in. apart, a row of spreaders every third row will be enough. A spacing of two to three feet apart in the rows is usually satisfactory. The spreaders should be located adjacent to the ties and opposite studs, as shown in Fig. 15, or the sheathing will be deflected out of line.

SECTION V—PLANNING THE JOB

Formwork is too frequently left to the carpenter foreman on the job to lay out and detail. Such practice is not desirable, since there is no time in which to plan and study the job after construction has started. The quality of the finished job and the contractor's profit or loss are dependent to a great degree upon the attention given to planning forms in the office and drafting room before a board is sawed or a nail driven.

Important Considerations

Each job must be studied individually at the time it is being estimated and when forms are being designed. No two jobs will be formed exactly alike. There are, however, certain important considerations applicable to all jobs and a thorough analysis of each should be made. They are:

1. Contemplated progress or speed of erection.
2. Length of time forms must remain in place (specified by architect or based on good practice).
3. Number of re-uses of material.
4. Type of forms to be used—panels, built-in-place, or a combination of the two.
5. If panels are to be used, shall they be detailed for re-use without alteration or shall they be cut down, added to and otherwise altered to fit varying conditions as the job progresses?
6. Location of construction joints.
7. Order of erection.
8. Must all erection be done by hand or will power equipment be used?
9. Order of stripping.

It is obvious that the person or persons who decide on the above questions must have the entire job in mind, since the inter-relationship of all the operations will have a bearing on how the formwork is to be planned.

Speed of Erection

The length of time for the completion of the entire job may be specified, or the contractor may be required to state in his proposal the number of days necessary. Out of the total time necessary to complete a building, it must be determined how much time will be required for the concrete work. The interior structural concrete, which is placed at the same time as the exterior architectural concrete, must be considered. In regard to the latter, the simplicity or elaborateness of the detail makes considerable difference.

The progress of a job will depend to a considerable extent on whether it is properly manned. In the carpenter gang, between 14 and 18 carpenters, and 6 and 9 helpers should be provided for every 10,000 sq. ft. of contact area of forms required for a single floor. This crew should complete one floor in about five or six working days of eight hours each. For larger jobs, an increase in the form area factor can be made because of the repetition of forms and the greater efficiency of the crew toward the end of a large job. A gang of the size mentioned can be expected to fabricate, erect and strip 10,000 sq. ft. of panel forms in 40 to 48 working hours, taking into consideration all types of forms used on a job. If all forms must be erected in place, the same crew will require between 10 and 20 per cent more working hours to construct and strip the same area of forms.

In the exterior walls, if the ornamentation requires the use of large areas of milled forms or waste molds, allowance must be made for the additional time required for erection and stripping. The exact amount depends upon the complexity of the detail, while the time required must be learned by experience. A study of a few typical examples will help as a guide to the estimator's judgment.

Fig. 20

A facade involving simple detail such as that illustrated in Fig. 20 requires only slightly more labor for forming than would be necessary if the fluted pilasters and the ornamental spandrels were plain. The fluting is flush with the wall surface, so it is unnecessary to cut the sheathing and no offsets need be formed. The fluting is formed by simply applying corrugated iron to the face of the straight wall forms as shown in Fig. 21. An allowance of 15 to 30 per cent additional time over that required if the walls were unornamented should be ample for constructing the outside forms for the entire area involving the ornament.

If the ornamentation is somewhat more elaborate, as that shown in Fig. 22, the forming time will be considerably increased. The application of the V-strips in the piers, the setting of waste molds for the spandrels, and the forms for the fluted mullions will increase the forming time from 75 to 100 per cent for the outside forms. The inside forms will require the average time to construct.

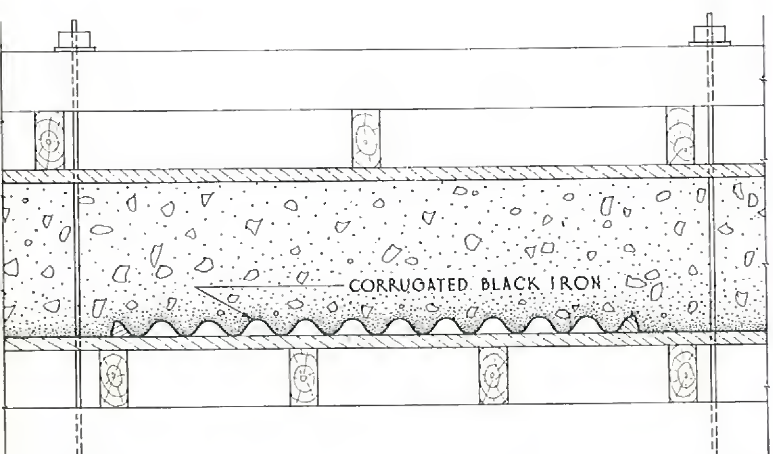


Fig. 21

Still more elaborate detail, particularly projecting cornices, water tables and ornament requiring the use of quite intricate waste molds, may increase the labor for erection and stripping still more for those areas. An extreme case may require two to three times the normal time for forming, but such jobs are unusual.

It is poor economy to force a carpenter gang to build more forms in a day than should normally be expected of them. Careless work will result which may cost more in the end.

The placing of reinforcing can usually be carried on simultaneously with the erection of forms, so that operation need not materially affect the time required for completion, assuming that the job is properly organized and an adequate crew of steel-setters is used. Four to six steel-setters and four to six laborers will set about four tons of reinforcing of average size in eight hours.

On the ordinary job the work should be planned so the maximum yardage of concrete to be placed in a day does not exceed the capacity of the mixer at the rate of one batch every two minutes. This rate allows for a mixing time of one minute and for unavoidable delays. If the job is large enough to warrant more than one mixer, the placing-rate will be in proportion to the number of mixers. Using a ½-yd. mixer, an average day's run will be 120 cu. yd. of concrete.

Fig. 22

To handle this yardage of concrete, a crew consisting of 20 to 25 laborers will be required.

Perfection of surface and quality of the exposed concrete must be the constant objective. Small mixers even under ½-yd. capacity are frequently used to advantage because the concrete is not delivered to the forms in too large quantities. Ample time must be allowed for spading, for a thorough job cannot be done if a large batch of concrete is dumped into the forms at one time.

Some account should be taken of additional time required for placing concrete in forms involving quite large areas of waste molds. If there are undercuts, it may be necessary to work the concrete into the mold by hand. More care is needed when spading around waste molds, to insure filling in the detail as well as to avoid damaging the mold. If there is a considerable area of waste molds, an allowance of 25 to 50 per cent more time should be required for placing the concrete against these molds than against ordinary forms.

The time required to do the various operations can be estimated within reasonable limits by applying the factors given above, In addition to the time required to actually do the work, is the time that must elapse between the placing of concrete and the stripping of forms. The allowance for shutdowns between the different operations can largely be eliminated by dividing the job into two or three parts so the work can be scheduled progressively.

Time Forms Must Remain in Place

Forms must be left in place long enough to allow the concrete to gain sufficient strength to support its own weight plus that of any construction loads. The forms serve another important purpose, namely, protection of the concrete against drying during the curing period. Although the curing of concrete can be accomplished satisfactorily by other methods as far as the quality of the concrete is concerned, it is often neglected, particularly on vertical surfaces. Leaving the forms in place a reasonable time is generally the simplest and best method to secure at least some degree of curing.

Regardless of the adequacy of the concrete to support its own weight, no forms should be removed from either exterior walls or interior frame and floors in less than four days, unless other means are provided for continuous moist-curing or high early strength cement is used. The time during which the forms must remain in place need not delay the progress of the work if a sufficient quantity of forms is available. Whether it is more economical to delay the job, awaiting removal of the forms, or to provide additional forms depends upon the overhead that goes on during delay and any penalties that may be invoked for over-running the specified time of completion, as compared to the cost of extra material.

Re-use of Forms

In order to maintain a progress schedule without delays, it is usually necessary to provide sufficient wall forms for one complete story and for one-quarter to one-half of a second story, depending upon the size of the job. If this is not done, at least part of the carpenter gang must be idle until forms can be stripped. If the job covers a very large area so the concrete required between successive construction joints exceeds that which can be conveniently placed in a day, the job may be divided into two or more parts. Under such conditions, enough wall forms for one entire part and a portion or all of the second part should be provided.

Because both the inside and outside of the building must progress together, at least one set of column forms, one set of slab panels and beam sides, two sets of beam and girder bottoms and two or three sets of shores will be required.

Type of Forms

Whether panel forms, built-in-place forms or a combination of the two should be used will depend very largely upon the architectural treatment of the building. It is almost axiomatic that panel forms should be used wherever possible without affecting the appearance of the job adversely, even though the panel is used only once and must be altered or completely made over. A saving in labor and material is made by doing as much work as possible on the bench and in the mill rather than off a scaffold. The use of the power equipment in the mill and the fact that the workmen have their feet on the ground result in greater efficiency. Progress of the work is facilitated because the panels can be made up in advance of time needed. Erection can proceed much faster, too, because each unit is planned in advance for a specific location and to fit adjoining panels. This is not so true of built-in-place forms even though fully detailed. About 50 to 100 per cent more re-use of sheathing and studs can be anticipated through the use of panel forms which can be used without alteration, than with forms built in place.

Spandrel and pilaster forms can usually be made in panels, unless the detail requires the use of waste molds or there are many angles and sharp corners in the ornamentation. Under such conditions, there would be danger of breaking corners when stripping if the form were removed as a unit. The quality of the finished job must always dictate the construction methods used. Never use a panel form where "piecemeal" stripping is required to insure perfection of detail, unless the panel is so constructed that it can be dismantled in pieces.

Panel forms are employed to greatest advantage where they can be used several times simply by raising them directly above their original positions. Fig. 23a is a good example of the type of elevation that lends itself to the use of panel forms. There are a large number

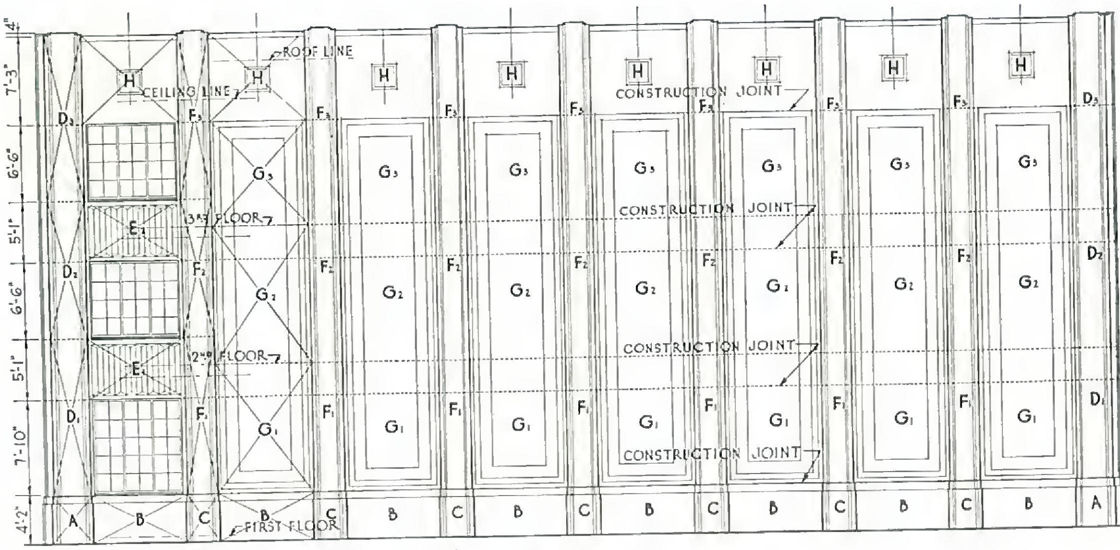


Fig. 23a

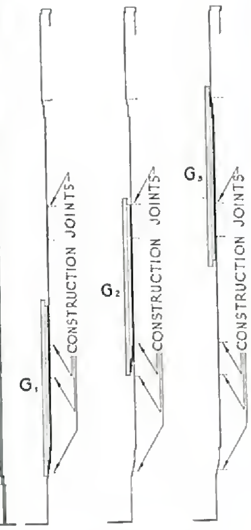


Fig. 23b

of elements of the same size, or sufficiently near the same, to permit alteration of the panels. A complete set of panels *A*, *B* and *C* would be provided for the entire building. These panels extend from the construction joint below the first floor to a joint at the top of the water table. The material in these panels can be re-used for building any of the forms above the water table. One complete set of panels marked *D*, *F* and *G* will suffice for building the entire height of the pilasters and the wall area between, by using them three times. One set of *E* and *H* panels completes the job.

Fig. 24 illustrates a typical job requiring that most of the forms be built in place. The spandrels are ornamented with considerable fine detail requiring either milled wood forms or plaster waste molds. The forms for the pilasters at the corners of the building and at each side of the entrance might be built as panels if special care is exercised in stripping. The fluted mullion forms, which must be lined with corrugated iron, may be built in place or constructed as panels, depending somewhat on the detail of the window jambs.

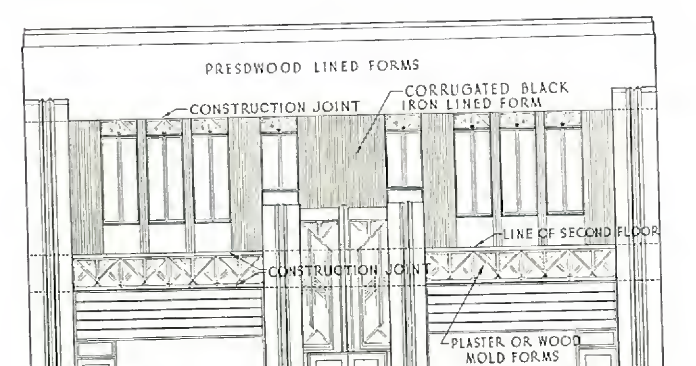


Fig. 24

Since the parapet is to have a smooth surface, as indicated by specification of Presdwood-lined forms, joints between panels would be objectionable, and no matter how much care is taken, the joints between panels are more noticeable than when the lining is carefully fitted in place. The backing can be made up in panels if the lining is applied after the panels are set as illustrated in Fig. 25.

Fig. 26 shows a facade that is best formed with a combination of panels and built-in-place forms. The detail up to the second-story window sills makes panel forms undesirable. For this part it would be best to erect the forms complete with sheathing as for a plain wall surface and then apply the necessary milled strips and pieces to form the detail. From this line to the head of the top-story windows, panels are ideal. Plywood panel forms would be especially well suited because each panel could be made from a single sheet. More than one piece should never be used where one will do, unless some pattern of joint lines is desired. If a board-marked surface is specified, the panel forms could be used, except for the parapet forms, which should be built in place in order to stagger the vertical joints in the sheathing. Panel forms made with ordinary lumber are unsatisfactory if two panels must join on a flat surface.

Alteration of Panels

Each of the panels required for the job illustrated in Fig. 26 can be re-used without alteration except for a slight change in the *A*-panels when used at the top of the pilasters. The conditions illustrated by Fig. 23 are quite different. Here the question must be answered, "Shall one *G*-panel be made that can be re-used without alteration for positions G_1, G_2 and G_3, or will it be better to change the panel to fit the different locations?"

The walls are to be built from the top of the water table to a construction joint at the head of the windows

which is also the underside of the floor girders. The next operation will complete the floor construction, a joint being located at the top of the slab. Incidentally, at the front of the building the joint would be jogged vertically to bring it to the window sill, thus avoiding a joint through the spandrel. The distance from the construction joint at the top of the second floor to the top of the third is slightly greater than from the water table to the top of the second floor. By making the *G*-panel long enough, without the offsets at the bottom, to fit the position G_2 as indicated in Fig. 23b, it can be used for positions G_1 and G_2 and then simply reversed for position G_3. A little greater length of panel than is needed for any one location must be handled each time, but much labor is saved by not altering the panel.

The *F*-panels must likewise be made long enough to fit the F_3 location. They can then be used in the other two positions simply by letting them project above the construction joints.

Construction Joints

When planning a job, the location of the construction joints must be determined. Sometimes the architect designates on his drawings where the joints must be located. If this is not done, the contractor should definitely decide where the construction joints should be. Their location must not be left to chance. Correct detailing of the job, the progress schedule and the appearance of the finished building are greatly influenced by the location of the construction or "cold" joints. If the location of joints is left to the contractor, he should submit his selection to the architect for approval. The chosen locations must satisfy all architectural and structural requirements.

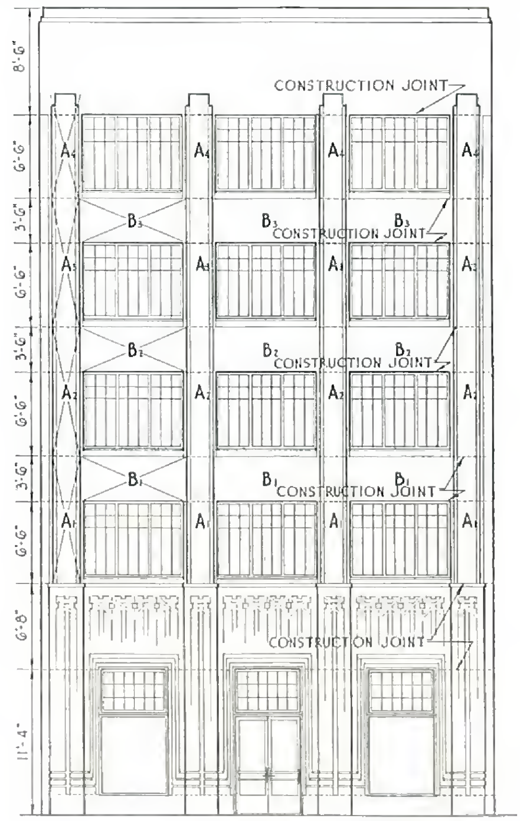


Fig. 26

Several factors must be taken into consideration. In the first place, joints must be close enough together so the quantity of concrete required between joints will not overtax the capacity of the plant and crew to place it in one normal working day. This is more important on an architectural concrete job than on one

Fig. 25

Fig. 28—Construction joints were carefully made on this job; being located as shown in Fig. 27 are inconspicuous. Borden Milk Co. plant, San Antonio; Atlee B. and Robert M. Ayres, architects; King B. Key, contractor.

in which the concrete serves a structural purpose only. The success or failure of the job is measured by the appearance when finished. If it is necessary to work several hours over-time, perhaps after dark, workmen are tired, there is an inclination to hurry, and careless workmanship results. Plan no more work than can be done easily in eight hours working at highest efficiency.

If panel forms are being used, the cold joints should be close enough together so the panels will reach from one joint to the next. In this way, intermediate joints will be avoided, which is conducive to good appearance.

Fig. 23 is a good illustration of the location of joints which is influenced by the foregoing considerations. A joint is placed below the floor girders and at the top of the slab so the quantity of concrete placed in one operation will not be too great. If the building is not too large, one joint can be eliminated, which is preferable. The panels required are rather long to avoid alterations, but they are not so long as to present any difficulty in handling.

It is always desirable to locate cold joints where they will be as inconspicuous as possible. Advantage should be taken of architectural details to obscure them. Although properly constructed cold joints need not be especially noticeable, the added precaution of placing them where they attract the least attention is desirable. For this reason, in Fig. 23 the joint at the top of the floor which unavoidably must be on the surface of the wall for the most part, is jogged vertically up to the level of the sill instead of cutting across the face of the spandrel. In Fig. 26 advantage is taken of the reveals and horizontal lines in the architectural detail to obscure the joints. By locating the joints at the sills and heads of the windows they are broken into short lengths on a natural line in the architectural treatment, which makes them inconspicuous.

Another example is that shown in Fig. 27 and the accompanying photograph of the completed building (Fig. 28). The joints are made as short as possible and are located at natural lines in the design. Note at the entrance, the joint which is at the window heads on each side is dropped down to the top of the door opening instead of cutting straight across the pediment. The joint below the first-story windows is at the top of the water table. The picture of the finished building shows how inconspicuous "cold" joints can be when properly located and constructed.

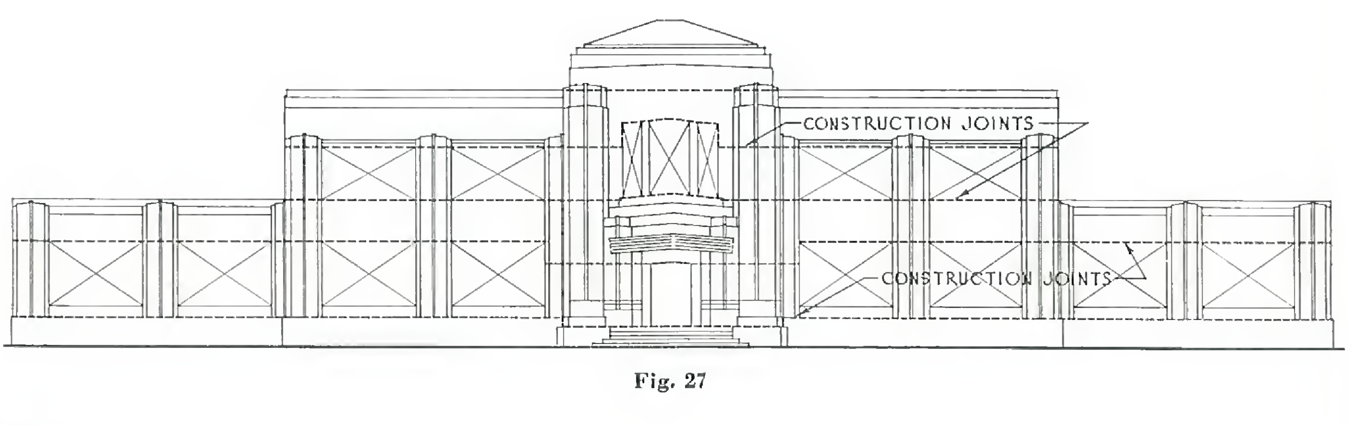


Fig. 27

In buildings of the column and spandrel type, such as shown in Fig. 29, the quantity of concrete in the columns is not large, so it may often be possible to avoid an actual construction joint at the window heads. The concrete, however, should not be placed in one continuous operation from window sill to window sill without interruption. The placing of concrete should be stopped at the window head and allowed to stand for an hour or longer, depending upon weather conditions to allow as much shrinkage as possible to take place before the spandrel and floor concrete is placed.

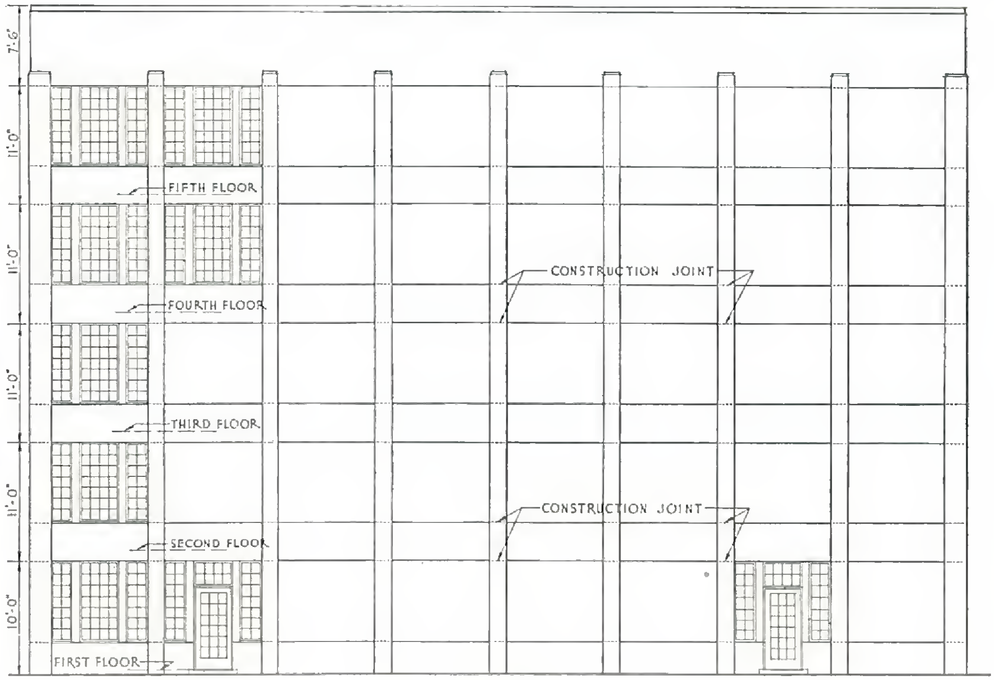


Fig. 29

Order of Erection

The order of erection of forms has a direct bearing upon the detailing and the scheduling of all operations from the ordering of material to its passage through the mill and finally to its use in the building. The erection schedule depends largely upon the type of building. There are three general plans of operations ordinarily followed in architectural concrete work.

Plan 1

For one and two-story buildings and the lower stories of tall buildings which are usually more highly ornamented than the stories above, the following procedure is recommended:

1. Erect the outside wall forms and bring them to line.
2. Erect the inside wall form and floor forms.
3. Check the alignment, tighten braces and bolts.

Plan 2

Buildings consisting principally of columns and spandrels are generally constructed with panel forms which can be handled most conveniently from a deck, so it is customary to:

1. Erect inside wall forms and floor forms.
2. Erect outside wall forms.
3. Bring forms to proper alignment, brace and bolt securely.

Plan 3

In tall buildings having considerable ornamentation necessitating the use of waste molds, milled wood and other special forms, the following procedure is best:

1. Erect floor forms.
2. Erect outside wall forms and bring practically to final line.
3. Erect inside wall forms.
4. Bring forms to final alignment, brace and bolt securely.

If this order of erection is followed, the outside forms can be touched up and joints in wood or plaster molds filled, if required, before the inside forms are set. The waste molds and panels for the outside can also be handled most conveniently by using the floor forms as a working platform.

Erection Methods

Built-in-place forms are from their very nature erected entirely by hand, piece by piece. The only aid that can be offered by mechanical equipment is in hoisting the lumber to the carpenters. In a panel form job, the planning of the job and detailing of the forms will be considerably affected by the use of mechanical equipment for erection.

Where hand methods only are used, no panel should weigh more than 300 to 400 lb., otherwise it cannot be handled conveniently by four men. Normally this will permit panels up to about 60 sq. ft. in area. It is not often that larger panels are required for wall forms. If larger panels are necessary, as in the job illustrated by Fig. 23, then a hoist will be required. The actual installation of forms on a similar job is shown in Fig. 30.

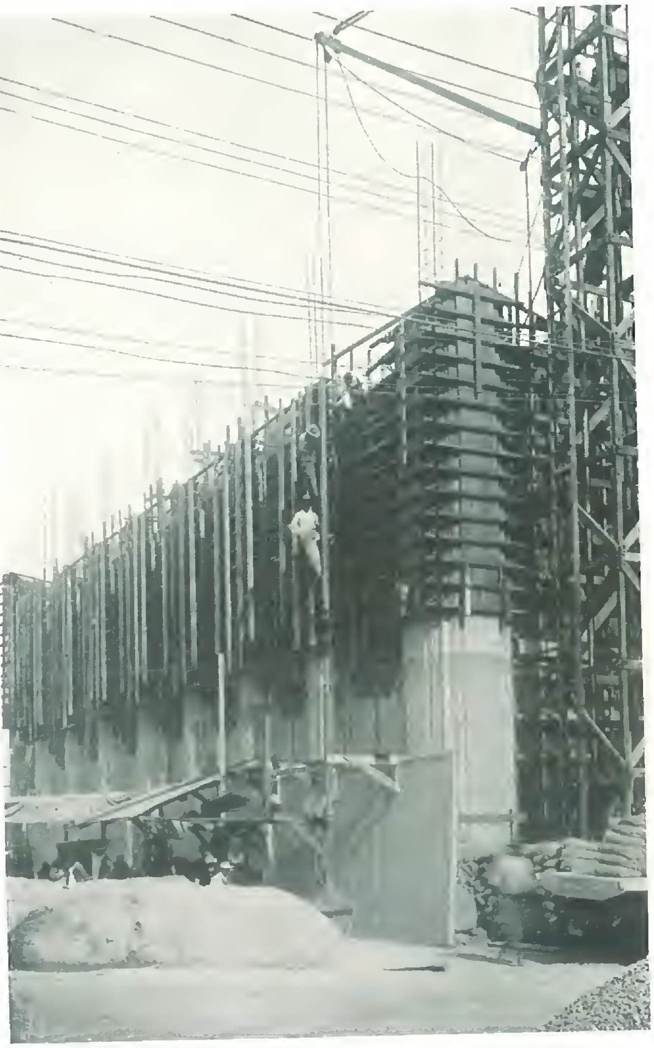


Fig. 30

A convenient rig for hoisting large panels is an "A"-frame derrick equipped with a ratchet windlass. The derrick is set up on the floor forms above or on the floor just finished, and tilted over the wall by means of guy-ropes until the sheave is in a position to hoist the panels and hold them while being secured in place.

Order of Stripping

Thought must be given to the order of stripping forms, whether built in place or made in panels. In the first case it is primarily in the erection of the forms that consideration should be given to the order of stripping; forms should be so constructed that it will not be necessary to break the lumber. Ordinarily, the order of stripping will be the reverse of that in erection, unless, in the case of panel forms, it is desired to re-use certain panels in advance of others. If possible, it is desirable to schedule the removal of panels so they can be removed and re-set in one operation. The detailing of forms to make stripping easy will be discussed in following sections.

SECTION VI—DETAILING

The job procedure having been planned by thoroughly analyzing the various considerations discussed in the preceding section, the next step is to detail the forms. Architects occasionally require that form details be submitted for approval in much the same manner as steel shop drawings. When not required to do so, the contractor can usually save time and money for himself by preparing key or assembly drawings and large scale details of the various parts. These drawings are given to the bench carpenters and to the foreman in charge of the erection crew for construction purposes. They are also very useful when ordering material.

The Panel Job

If panel forms are to be used for an entire job or a major part of it, a key drawing showing the location of panels of the same size and shape is indispensable. Such a drawing need be only a skeleton or outline drawing without details and generally without dimensions. The architect's drawings of the building elevations may be used simply by outlining the panels in their respective locations. Each panel should be given an appropriate mark to signify those having the same dimensions and details. By means of subscripts, or other identifying

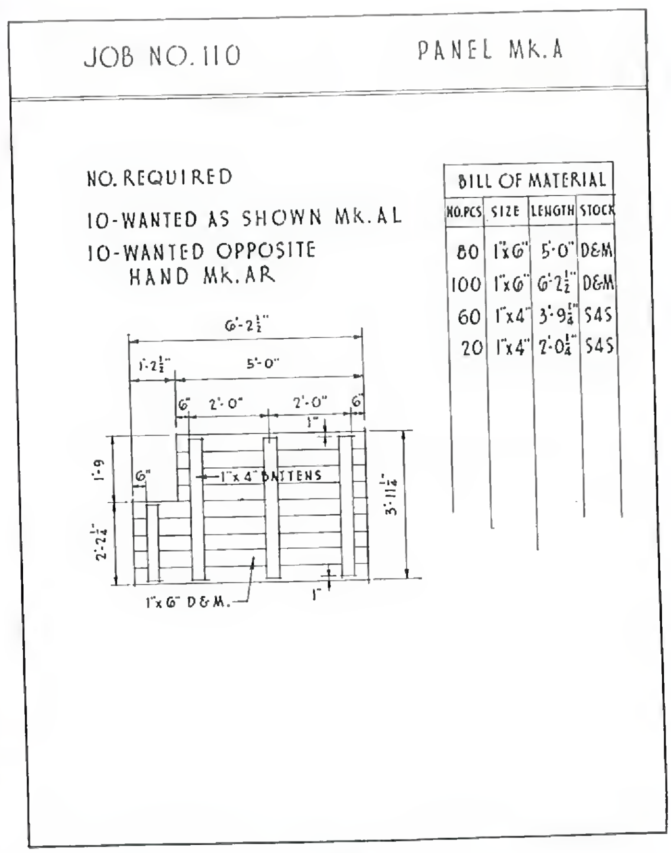


Fig. 31

numbers, the order in which each panel is to be used can be indicated. If the architect's drawings contain so much detail as to make them difficult to use as a key drawing, a tracing can be made showing the principal outlines which will define the divisions between panels. Figs. 23 and 26 are typical key drawings for panel form jobs, except that more detail is shown than is necessary in order to illustrate certain points discussed in the preceding section.

A detail drawing, such as shown in Fig. 31, should be made of each panel and only one panel shown on a sheet, except that rights and lefts may be called for on the same sheet. The detail should bear the mark number corresponding to the key drawing, and the number of such panels required should be shown. All essential dimensions must be given so that bench carpenters or mill men need not refer to the architect's drawings. The spacing of studs and/or cleats should be given, and the number of boards required for sheathing should be shown if ordinary lumber is used. For the average job, it is not necessary to give a distinguishing mark to each piece of lumber making up a panel, because the mill man or his helper will select from the stock piles the material required for the panels to be made at that time. He will do the necessary ripping and cutting and will then turn over the material for panels of a certain mark to the bench carpenter, who will fabricate the panels from the details given him with the material by the mill man. On an exceptionally large job, it is desirable to give all pieces a mark. The mill man then prepares the material according to a list furnished him by the route clerk. The labor foreman bundles and labels the number of pieces of each mark required for a certain form and delivers the bundles to the bench carpenter who, in turn, fabricates the panels in accordance with the details given him by the route clerk.

On each detail sheet there should be a lumber schedule listing the number of pieces required, their sizes, lengths, and mark numbers if the individual pieces are marked. Knowing the number of panels required for the job, the total amount of lumber required for the panel forms can be determined readily. Wales, braces, kickers and such lumber as may be needed for built-in-place forms must be estimated separately.

The Built-In-Place Job

The key drawings for the job in which most of the forms are built in place are usually the architect's large scale drawings supplemented by such other drawings made by the contractor as may be necessary to show fully the form construction. It will usually suffice to show only the sheathing, wood molds and plaster molds in direct contact with the concrete. If the studs at corners, reveals and other places where a more or less complicated arrangement is necessary are shown, it will facilitate erection and stripping. Wales and ties need not be shown, as a rule, although to do so will save time on the job by relieving the foreman and workmen of all but the mechanical operation of form erection. The maximum spacing of studs, wales and ties should be mentioned on the drawings.

All drawings must be fully dimensioned, except that detailed dimensions need not be given for waste molds which are to be cast from approved models. Over-all dimensions of waste molds should be shown to enable the mold-maker and carpenter foreman to lay out their work on the same basis.

Fig. 32 is a typical key drawing. The elevation represents the architect's drawing of a frieze. The sections may be the architect's drawings on which the forms have been drawn by the contractor, or they may be prepared by the contractor expressly for the purpose of showing the form construction.

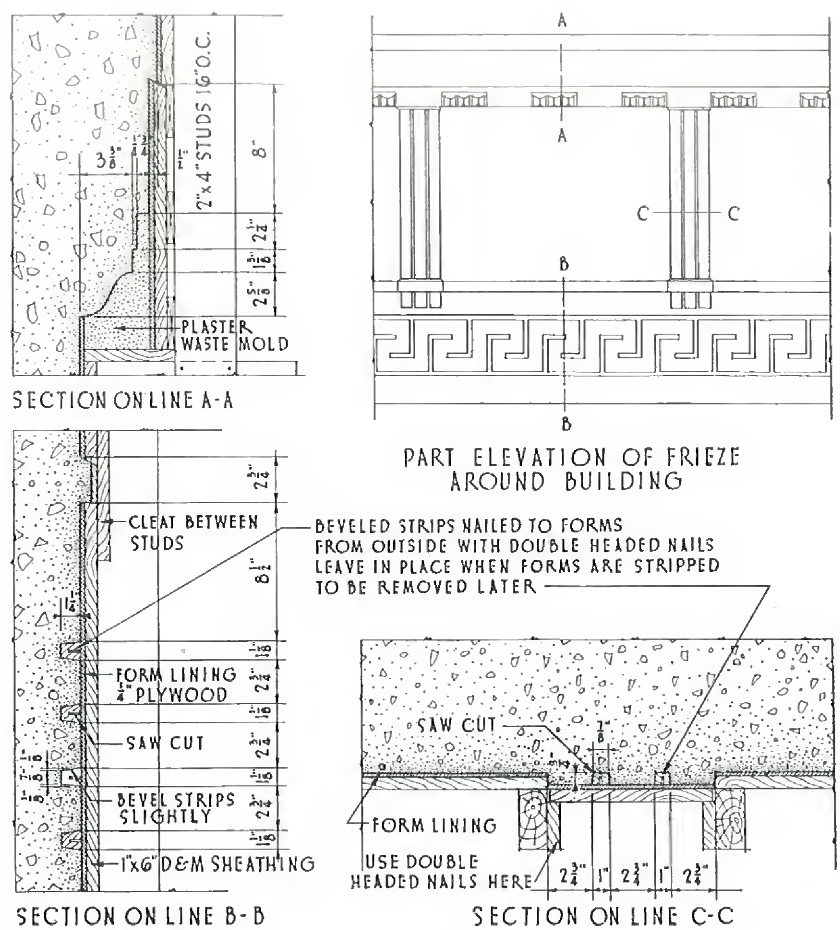


Fig. 32

SECTION VII—KINDS AND GRADES OF LUMBER AND WHERE USED

Practically all formwork, regardless of what may be used as the contact surface with the concrete, involves the use of lumber. The quality of the finished job is dependent to a considerable extent upon the kind and quality of the lumber used. In general, any lumber that is straight, structurally sound, and strong and thoroughly seasoned is suitable. However, only the softwoods or the woods of coniferous trees are used for form lumber. In general, they are easier to work, though not all species are softer than some of the so-called hardwoods. The softwoods are usually lighter in weight, which is an advantage. Because of the wide distribution and abundance of the softwoods they are the most economical for all kinds of formwork.

Kinds of Lumber

Among the softwoods, *Longleaf Southern Yellow pine* and *Douglas fir*, sometimes called *Oregon pine*, are the most widely used for all purposes in building structural concrete forms, and are equally suitable for architectural concrete. In common with all softwoods, they are easily worked and are the strongest woods in that group. Both hold nails well and are durable, which makes for economy by allowing maximum re-use of material. These species are used for sheathing, studs and wales, and *Douglas fir* is used to some extent for milled wood forms.

Douglas fir is appreciably lighter in weight than *Southern pine* and is a little softer, making it slightly more desirable. Both materials can be obtained in their respective markets in all sizes and grades of boards, dimension and timbers. Where both materials can be obtained in local markets, the choice between the two should be primarily one of cost, as there is little difference between the two materials.

California redwood is used to some extent for structural concrete forms in the markets where it is available and it is an excellent material for many uses. Its use for architectural concrete work, however, cannot be recommended because of its tendency to stain the concrete. Even for studs and wales, *redwood* is not suitable because when the wood is wet the stain may drip onto an exposed surface.

West Coast hemlock is comparable to *Douglas fir* as form lumber and may be used wherever *Douglas fir* or *Southern pine* is used, although it is not quite as strong, as indicated by the safe working stresses given in Table 1. The species of *hemlock* growing on the Pacific Coast should not be confused with *Eastern hemlock* which is not generally considered suitable for architectural concrete forms although used to quite an extent for structural concrete.

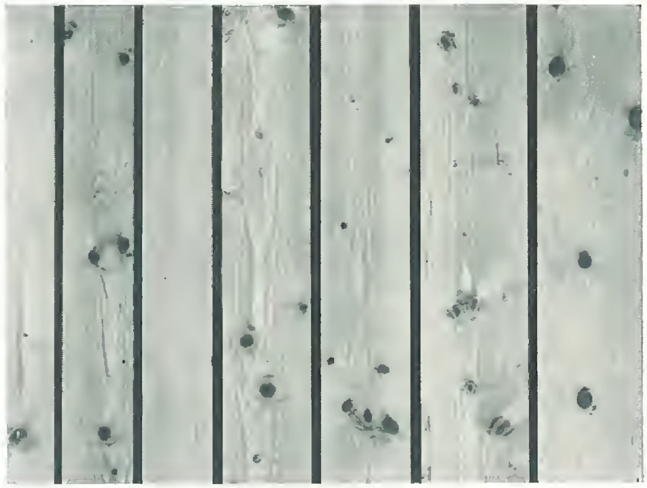


Fig. 33a—No. 1 Common Boards.

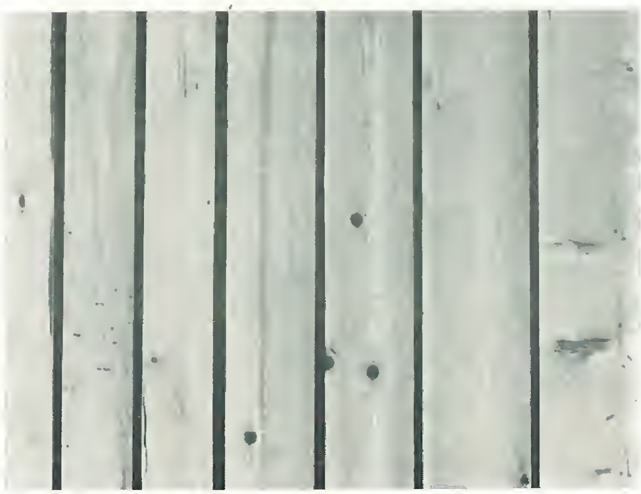
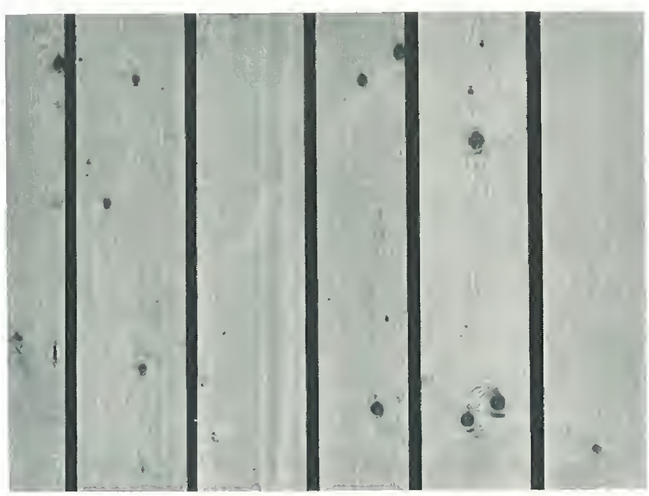


Fig. 33b—No. 2 Common Boards.



Photographs Courtesy West Coast Lumbermen's Association

Fig. 33c—No. 1 Common Dimension.

Grades of Douglas fir commonly used for sheathing, studs and wales for architectural concrete forms. West Coast hemlock is same in general appearance and grading as Douglas fir.

Northern White, Idaho White, Sugar and *Ponderosa pine* are all excellent woods for architectural concrete forms. Since these woods are not as abundant as *Douglas fir* and *Southern pine* and are used for purposes for which the latter are not so well suited, they are not generally economical for forms except for special uses. Because the white pines are soft and straight-grained, they are especially well suited for run moldings and milled forms for ornamentation not requiring plaster waste molds. The white pines also have the quality of staying in place well, as they are not inclined to warp and twist. This is an especially desirable quality for forms made up of an assembly of milled pieces, as they will remain tight, insuring sharp details. *Norway pine* and *Eastern spruce* have many of the qualities of the white pines and may be used in place of them, providing satisfactory grades can be obtained.

Grades, Sizes and Patterns of Lumber

The lumber used for architectural concrete forms, particularly for the contact surface, should be of a higher grade, as a rule, than would ordinarily be used for structural concrete work. This is especially true where relatively smooth surfaces free from blemishes are desired. In general, the use of No. 1 dimension and boards, though costing slightly more than lower grades, is economical because the upper grade is more sound and straight and therefore requires less labor for construction. A greater number of re-uses can also be obtained from No. 1 material than from second and third grades. If forms are to be used only once, No. 2 dimension is satisfactory for studs and wales, but No. 1 boards should always be used for sheathing unless an impression of knots and other flaws in the wood is desired in the concrete for architectural reasons.

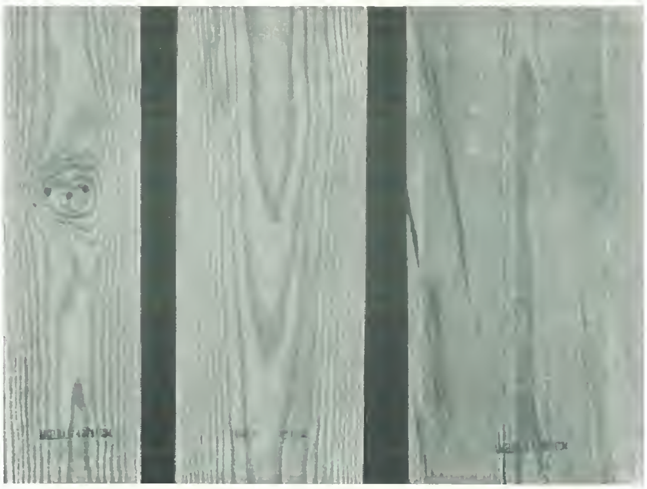
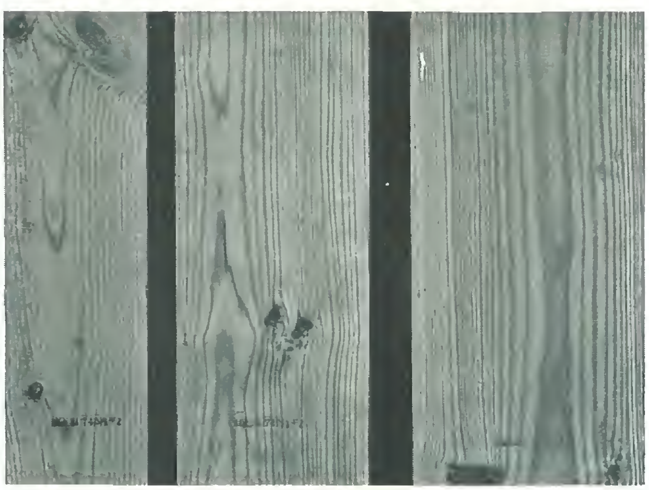


Fig. 34a—No. 1 Common Boards.



Photographs Courtesy Southern Pine Association.

Fig. 34b—No. 2 Common Boards.

Grades of Long Leaf Southern pine commonly used for architectural concrete forms.

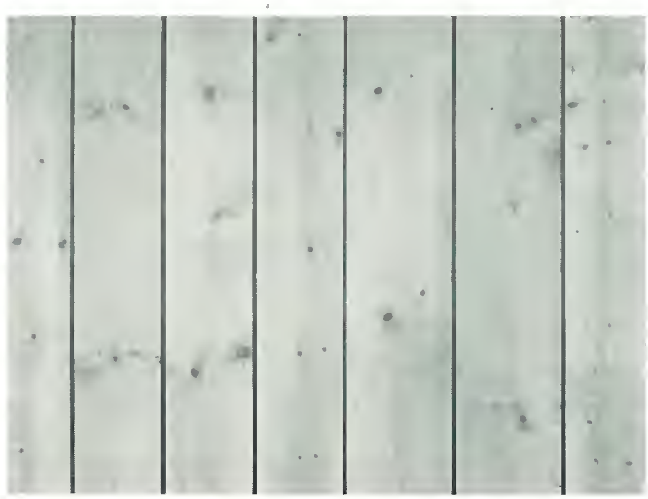
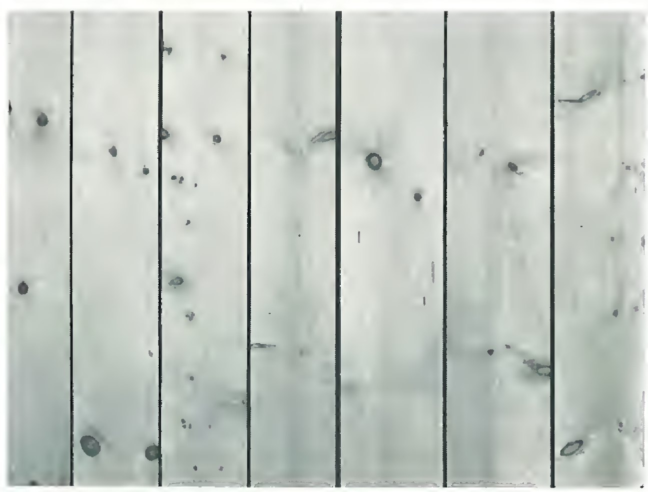


Fig. 35a—No. 1 Boards.



Photographs Courtesy Western Pine Association.

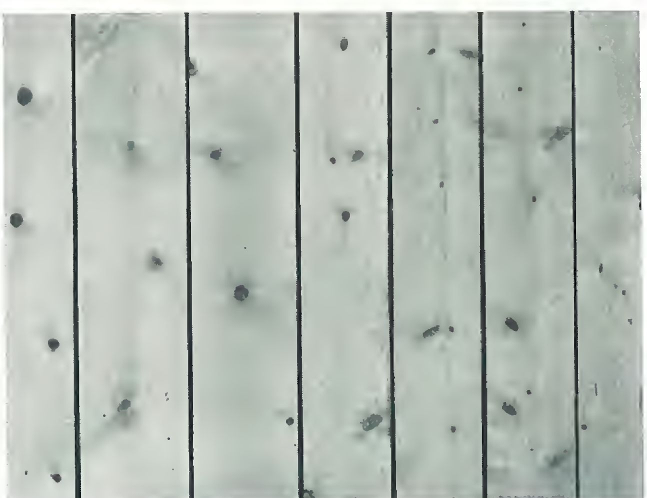
Fig. 35b—No. 2 Boards.

Grades of Idaho (Genuine) White pine boards used for wood moldings for architectural concrete forms.

There is an appreciable difference in the quality of different woods of the same grade designation. While almost all the softwoods are graded in accordance with the American Lumber Standards, the various regional lumber manufacturers' associations have drafted grading rules which apply to the species produced by their members. The inherent characteristics of the various woods have been taken into consideration in establishing the different grades. *Whenever No. 1 or other grades of lumber are mentioned in this booklet, they shall be understood to mean the grade designation of the regional lumber association of manufacturers producing the specie of lumber recommended for the purpose being discussed.*

Although the white pines are not generally used for ordinary sheathing or for studs and wales, in some markets it may be economical to use those woods in place of *Douglas fir* or *Southern pine*. If so, the next lower grade than that recommended, which is based on *Douglas fir* or *Southern pine*, may be used.

Fig. 36a—No. 1 Ponderosa Pine Boards.



Photographs Courtesy Western Pine Association.

Fig. 36b—No. 2 Ponderosa Pine Boards.

Grades of Ponderosa pine boards commonly used for wood moldings for architectural concrete forms. No. 1 and No. 2 Sugar pine boards, also used for wood moldings, are comparable in general appearance with Idaho White and Ponderosa pine of similar grade designation.

Particular care should be used in the choice of sheathing lumber. If the finished surface is to be uniformly smooth and to show only a slight impression of the joint lines and grain marking, No. 1 dressed and matched boards uniformly sized should be used. For especially smooth surfaces where a form liner is not used, *C*-grade vertical or flat-grain thoroughly seasoned flooring or select merchantable boards should be used.

For smooth surfaces, it is essential that tongued and grooved lumber be used in order to hold the sheathing in alignment, thus preventing offset joints which would detract from the smoothness of the surface. The matching of the boards also serves to prevent leakage through the joints, which otherwise causes slight fins that accentuate the joint lines. Fig. 37 illustrates the surface obtained with tongued and grooved dressed sheathing.

Fig. 37

Sheathing lumber, even though oiled, has some tendency to warp or cup. This tendency is more pronounced in wide than in narrow boards. It is evident, therefore, that the impression of the joint lines between boards can be emphasized or reduced by selecting wide or narrow sheathing. For average work, 6 in. wide boards are used. There is a slight advantage in using 4-in. boards or flooring where a very smooth surface is desired, while 8 and 10-in. boards make the joint lines more pronounced due to cupping.

Labor can be saved by using center-matched boards or flooring (Fig. 38a) rather than standard-matched (Fig. 38b), in which the tongue and groove are off-center, because it is not necessary to turn the boards when applying them to the studs. Greater re-use can be had from center-matched lumber, because boards can be reversed if one side has become damaged. It is also an economy measure to order sheathing lumber loose run, as less labor is required to draw the boards up tight, especially after the first use, because the

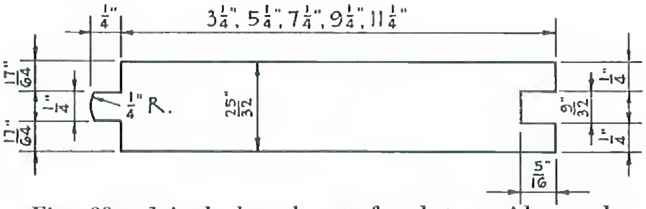


Fig. 38a—1-inch boards, surfaced two sides and center-matched (*S2SCM*).

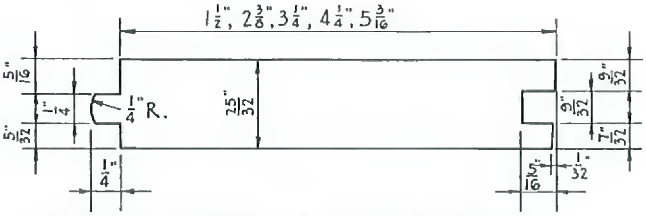
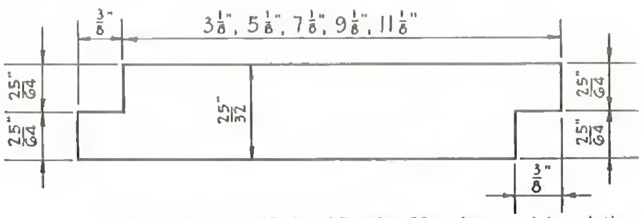


Fig. 38b—1-inch flooring, standard-matched

swelling of the lumber may make the tongue larger than the groove unless this precaution is taken.

Shiplap (Fig. 39) is used to some extent in place of tongued and grooved boards for sheathing. It is not quite so desirable for the smoothest surfaces, because there is more tendency for the boards to offset slightly. A little more re-use can sometimes be obtained as there is less chance of splitting the edges when stripping.



Diagrams Courtesy National Lumber Manufacturers' Association.

Fig. 39—1-inch shiplap boards. (In some woods the lap is ½-in. wide.)

Rough-textured surfaces that show pronounced grain marking and joint lines between form boards, as illustrated in Fig. 40, are obtained by using re-sawed square-edged lumber. For a surface showing only a mild accentuation of the joint lines, No. 1 boards surfaced one side and two edges are used, and the rough side of the lumber is used as the contact surface. The surfacing of the edges is necessary to straighten the boards so they can be drawn tightly together. Dressing one side of the boards reduces the variation in thickness so the offset between adjacent boards is not so great. For very rugged textures, neither side of the sheathing should be surfaced. The grain of the rough lumber will show plainly in the finished concrete even though any raising of the grain is prevented by oiling the forms. If it is desired to have the grain marks even more pronounced, the grain can be raised by wetting the lumber before oiling. A still more effective method is to spray the sheathing lumber with ammonia. The rough-textured surface obtained from forms treated in this manner is appropriate for certain styles of architecture and provides an especially good bonding surface for a stucco finish.

The lumber used for backing for Presdwood and other lining materials need not be of as high grade as that used for contact surfaces. It is necessary, however, that the sheathing lumber be sized to uniform thickness and T and G material should be used to prevent offset joints if a lining material less than ¼ in. thick is used. If square-edged or rough lumber is used for backing, the joint lines may show through, especially in bright sunlight, due to slight shadow lines. Wide boards accentuate this effect due to cupping, just as in surfaces formed in direct contact with the form boards. Since it is usually the purpose of a form liner to obtain the smoothest possible surface, every precaution possible in the selection of the backing material should be taken to avoid an impression of the boards showing in the finished concrete. Near the ground or at places of close observation, it is advisable to use 1x4 flooring for sheathing to minimize cupping, particularly if ⅛ in. thick lining material is used. Knots, shakes and checks, if not sufficient to weaken material greatly, are not particularly objectionable in boards for backing, so No. 2 and No. 3 grade lumber are usually satisfactory.

As previously stated, the soft, close-grained woods, such as the *Idaho*, *Ponderosa* and *Sugar pines*, *Norway pine* and *Eastern spruce*, are best suited for run wood moldings and other milled forms. The grade of lumber used for this purpose should be quite free from pronounced defects which might mar the perfection of detail desired. Grading rules vary somewhat and the various grades of the white pines are higher than the grades of similar designation in *Douglas fir* or *Southern pine*. For the average milled forms, however, nothing lower than No. 2 grade material should be used. For quite fine, intricate detail, No. 1 grade should be specified to secure material more free from knots and other slight defects.

All lumber for forms should be well seasoned. This is especially true for milled forms in which an assembly of pieces is used, for the precision with which the various parts fit together determines the sharpness and perfection of the finished detail. Shrinkage, due to drying after the forms are erected, is quite rapid and causes the joints between

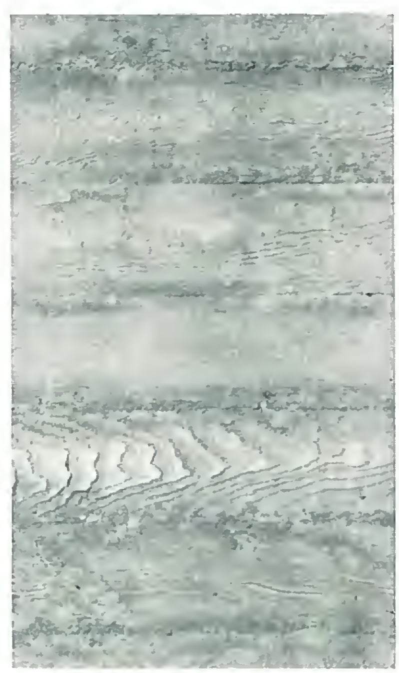


Fig. 40

boards to open if green lumber is used. Even with the best seasoned material, if the forms are allowed to remain in the sun several days before placing concrete, the joints may open enough to permit formation of small fins unless proper precautions are taken. When this occurs, the forms should be wet a day or two before concreting, to cause the lumber to swell and tighten the joints; otherwise pointing with water putty or similar material may be necessary. If forms must be wetted to swell the wood and close the joints, special care should be given to inspection to be sure the forms have not been thrown out of alignment by expansion and contraction.

Re-uses

The re-use of form lumber depends upon a number of factors; consequently, the individual job must be considered when preparing an estimate. The details and irregularities of the walls in some jobs may make any appreciable re-use of material impossible. Small buildings must often be formed very largely at one time, making it necessary to have enough lumber to form the complete job. Even on large jobs where some re-use of material can be made, the scheduling of the work will affect the number of re-uses. On the average job, however, a considerable re-use of form lumber is possible, if care is given to planning and detailing. Exact rules can not be given but experience offers a guide to the estimator's judgment.

Assuming the use of No. 1 *Douglas fir* or *Southern pine* sheathing, about two re-uses of the material may reasonably be expected, providing the job is of sufficient size and the construction schedule will permit. If most of the job is formed with panels that do not require much alteration, three or four re-uses can usually be obtained. Sheathing lumber used as backing for a form liner can generally be used twice as many times as when used as the contact surface.

On the average job, a sufficient quantity of dimension material should be provided for one complete set of forms and 15 to 20 per cent additional allowed for breakage and waste. This quantity should be adequate for the entire job.

The grade of lumber used has an important influence on the number of re-uses that may be expected. No. 2 and No. 3 grade lumber, if permissible as far as the quality of the finished job is concerned, can seldom be re-used except to a limited extent for studs, wales and braces, or for sheathing for lined forms. Generally, it is unwise to figure on more than one-half as much re-use of No. 2 lumber as of No. 1 and not more than one-third the re-use from No. 3 grade.

The detailing of forms to facilitate stripping without breaking the lumber will materially affect the number of re-uses that can be obtained. Furthermore, by being careful when stripping, much needless damage to material can be prevented. Proper cleaning and preparation of lumber for re-use are also important. The subjects are more fully discussed in other sections.

SECTION VIII—FORM LININGS

The use of form liners has been mentioned as a means of producing surfaces practically free from any joint marks and in which grain marking is barely discernible or entirely absent. While the term "lining" implies a covering over another material, it is here intended to mean a material in large sheets which may be nailed directly to the studs or applied over ordinary sheathing lumber. The two most common form liners are plywood and Presdwood. Metal is used to some extent but generally for some special detail only and not over an entire wall area. Metal molds and linings are discussed in Section XI.

Plywood

The plywood used for formwork is made of high grade *Douglas fir* and has all the desirable qualities of that lumber for such use. The panel faces must be free from knots, open defects and sap. Since plywood is made up of three or more laminations of thin sheets of wood in which the grain in successive layers is at right-angles, it is quite warp-resistant and will not split, which greatly increases the re-use of the material. The number of re-uses depends largely upon the cementing material used to bind the plies together. Only board made with a water-proof "glue" is suitable for formwork. Common plywood used for packing cases and construction within buildings where it is always dry must not be used for formwork. Some plywoods are made with animal or vegetable glues that are very satisfactory and from 3 to 5 re-uses of the material can be expected if not too badly cut up. Board made with a resin-base glue and hot-pressed is even less affected by moisture than that in which animal or vegetable glue is used and 6 to 8 re-uses are not unreasonable to expect. A greater number of re-uses should not be expected ordinarily for architectural concrete work, since the surface of the board will become so marred as to make it unserviceable, although still strong and satisfactory for structural concrete forms. If panel forms can be used with only minor altering required, 50 to 100 per cent more re-use of any sheathing or lining material can be obtained than in built-in-place forms. Plywood oiled at the mill and then re-oiled on the job before being used will give better service than when oiled on the job only, because the oil penetrates the fiber better, thereby more effectively preventing raising of the grain, separating of the plies and excessive checking.

Plywood may be had in thicknesses ranging from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. in $\frac{1}{16}$-in. increments. Except for curved forms, the $\frac{9}{16}$, $\frac{5}{8}$ and $\frac{3}{4}$-in. thicknesses are most commonly used for formwork.

Any width of sheet desired, up to 48 in., can be obtained from the mills, although frequently only the 36 and 48-in. widths are carried in local yards for quick delivery. Sheets 24 in. and under are given the base price. For widths greater than 24 in., there is an extra

Fig. 41

charge which increases for the 36 and 48-in. widths. It may therefore be economical to use the narrower widths unless, by so doing, more labor is required or the number of joints may be objectionable. For the sake of appearance, two widths should never be used where one will do, unless the architectural design requires a certain arrangement of joint lines. Fig. 41 shows the result of using odd-sized pieces of plywood and joints not properly made. Fig. 42, on the other hand, shows the pleasing effect obtained by using sheets of uniform size and by exercising care in the making of tight, smooth joints.

Plywood, at the base price, is made in standard lengths up to 8 ft., which is the most common length used for formwork. Longer lengths up to 12 ft. may be obtained from the mills, but a premium must be paid.

The ¼-in. and ⅜-in. plywood is made of 3 plies and heavier panels are made of 5 plies. Plywood thinner than 9/16 in. requires a backing to prevent deflection that would be noticeable in the finished surface. The ¼ in. and ⅜ in. thick sheets must be backed up solidly, otherwise the deflection between sheathing boards will be noticeable. It is usually more economical to use the 9/16-in. or thicker material without backing, than to use the thinner material with a tight backing, except where the architectural detail requires cutting the form material into small pieces, precluding re-use of the lining. The ¼-in. plywood is useful for curved surfaces. It can be bent to a 3 or 4-ft. radius without steaming and to a smaller radius if steamed. The labor involved to force plywood into a shorter-radius curve and the difficulty of holding it is not warranted. A simpler method of forming short-radius curves is described elsewhere. When thin plywood is bent, it may be used without tight backing, but the supports should not be farther than 10 or 12 in. apart.

For built-in-place forms in which ¼-in. and ⅜-in. plywood is used, the plywood should be nailed at about 4 to 6-in. intervals along all four edges with 3*d blue shingle* nails. These nails are small enough to permit easy stripping without damaging the plywood, but have adequate holding power to secure the lining in place. It is desirable to nail the lining with at least one nail to every square foot throughout the surface to prevent any tendency to bulge. The edges of abutting sheets should be nailed to the same backing board to insure a smooth joint. Where forms are built in panels for repeated use, a somewhat closer nailing is desirable or else slightly larger nails should be used to reduce the amount of repairing necessary to keep the panels in good condition.

Plywood 9/16 in. thick and heavier is used without backing, the plywood being nailed directly to the studs. The load-carrying capacity of plywood is considerably greater when the span is in the direction of the grain of the outside plies, hence the deflection will be materially less if the studs or other supports are at right-angles to the grain of the outside plies. The spans

Fig. 42—The plywood form lining on this job was used in such widths as to bring all joint lines to level planes and to principal lines in the design. Venice High School, Venice, Calif.; Austin and Ashley, architects; Clinton Construction Co., contractor.

between supports for plywood under various loads shown in Table 9 are based upon the assumption that the studs will be located in such a way as to take advantage of the greatest strength of the board. If it is necessary to have the studs parallel to the grain of the outer plies, the distance between studs should be 25 per cent less than that shown in the table.

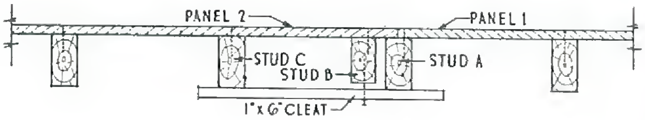


Fig. 43

Whether forms are built in place or in panels, the joints between sheets of plywood which are parallel to the studs must be made directly over a stud. This is the obvious thing to do when forms are built in place, but the importance of it is sometimes overlooked when using panels. A method of detailing panel forms to secure good alignment and inconspicuous joints is illustrated by Fig. 43. Panel 1, of which Stud *A* is the edge stud, is first set in position. The plywood sheathing of Panel 1 laps over Stud *A* only to the center, leaving the other half to receive the edge of the sheathing of Panel 2. Stud *B*, which is the edge stud of Panel 2, is ¼ to ½ in. less in depth than Studs *A* and *C*. The 1x6 cleat bears against Studs *A* and *C* and is nailed with a double-headed nail to Stud *B*. This will draw the sheathing of Panel 2 snugly against Stud *A*, making a very inconspicuous joint provided the plywood has been cut to a smooth, straight edge. The sheathing of Panel 2 is not nailed to Stud *A*, so the panels can be stripped simply by removing wales and 1x6 cleats.

Plywood can be cut with a hand or power saw and if a fine saw is used, a sufficiently smooth edge can be made to make dressing with a plane unnecessary for most work. For the very finest job, it is advisable to smooth and straighten sawed edges with a plane. After the forms are erected, slight irregularities in alignment of abutting sheets of plywood can be removed with a block plane. Small wooden wedges may be driven between the plywood and the stud at a joint to bring the sheets into good alignment as shown in Fig. 44. Note that the studs are horizontal and the wales vertical in this example. The grain of the plywood runs vertically so as to take full advantage of the strength of the material. Pieces of 2x4 are cut in between the studs for headers at the vertical joints in the plywood to provide a firm backing to which the edges of the plywood are nailed.

When plywood is used for panel sheathing applied directly to the studs without backing, the studs should be spaced about 2 in. closer together than required for the pressure as indicated in Table 9. This is necessary because, as the panels are re-used, there is a tendency for the plywood to take on a slight permanent set with each use until deflection may be noticeable. A maximum stud-spacing of 14 in. is advisable with ⅝-in. plywood sheathing in panel forms.

Fig. 44

Presdwood

Presdwood is extensively used as a form liner in architectural concrete work where smooth surfaces entirely free from any trace of grain marking are desired. The material is made of wood chips which are torn into shreds by an explosion process with high-pressure steam. The fibers are then compressed under very heavy pressure and at a high temperature. The board is finally treated to minimize absorption. This process is called tempering and only the tempered board is suitable for concrete formwork. The untempered board has too great absorption, causing it to swell and buckle, and the surface to become spongy. *Wherever Presdwood is mentioned in this booklet, it shall be understood to refer to Tempered Presdwood.*

The face surface of Presdwood is very smooth and when new has a semi-polish. It is this face that is normally used as the contact surface of the form. Where an unusual effect is desired, the back of the board, which has a screen-mesh-indented surface, is used in contact with the concrete. Because this side does not have a polished surface, it is more absorbent than the other and fewer re-uses can be obtained.

The number of re-uses that can be obtained is dependent largely upon the way the material is used. When used as a liner for built-in-place forms, three or four re-uses are the maximum that can be expected,

SECTION IX—WOOD MOLDS

The choice of wood or plaster molds to form architectural concrete ornament is dependent upon the type of ornament, the amount of repetition and, sometimes, upon the ability of the local mill or ornamental plasterer to produce the required molds. Wood molds are made of white pine, soft vertical-grain *Douglas fir* or other soft wood which is run to size and shape in a commercial mill, or in the job mill if the job is large enough to warrant installation of the necessary shapers. Because of the method of manufacture, wood molds are best adapted to ornament consisting of simple moldings, combinations of moldings, or shapes that can be made with a band saw. Detail involving carving or undercuts should be formed with plaster waste molds. Wood molds are easier to erect and strip than are plaster molds. Less work is required to prepare them for use on the job and they do not require the care in handling necessary with plaster molds. It is therefore advisable to use wood molds wherever possible, resorting to plaster molds only when the detail cannot be formed in any other way. Figs. 46 and 47 show buildings involving types of ornament best formed with wood molds.

The joints in wood molds should be made to prevent such leakage of mortar as would make objectionable fins. Wherever possible, at corners and elsewhere in the assembly of the various members of a wood mold, make the joints by overlapping the pieces as illustrated in Fig. 48 rather than by butting or mitering them. Slight movement due to alternate swelling and shrinking will not open the joints if they are made in this way. Where the detail is such that members must be joined where there is no return or reveal, use tongued and grooved or shiplap lumber or spline the joints. Square-edged butt joints are satisfactory for moldings applied to a solid backing.

If several pieces are required to make a complete mold, as for a cornice or belt course, the joints in the different members should be staggered. By so doing, the mold will be more rigid and less likely to get out of alignment. A better appearance is obtained by breaking the joints, because the short joints in the various pieces can be pointed with water putty, making them practically invisible so there are no distinct breaks in the continuity of the design.

Much time can be saved in the erection and stripping of the forms for a detail involving many pieces of run moldings, if brackets are made in the mill to a template to fit the general profile of the detail. The section in Fig. 48 illustrates this point. The studs for the wall forms are cut off at the line *X-X*. The brackets consisting of pieces *A*, *B* and *C* which have been assembled in the mill are scabbed to the studs. The wales bearing on piece *A* and the lower half of the wale bearing on piece *C* are put in place to hold the brackets, which are spaced at about 16-in. centers, in alignment. The cornice members are then applied. Pieces 1, 2, 3 and 4 are moldings and all other pieces are ripped to size from stock lumber on the job or in the mill. Note the saw-cuts in the backs of the moldings to prevent warping and wedging of the lumber which might result in broken edges. Fig. 49 shows an alternate method of forming the same detail which, though not quite as quick to erect, is substantial and will produce good results.

No matter how carefully oiled, there is a tendency of all wood to swell slightly when wet. Accounts must be taken of this fact when detailing and building wood molds, perhaps even more than for straight wall work, because of the possibility of breaking the corners of detail if the molds swell and bind. Thick, wide molds

Fig. 46—The checkerboard design above the second story windows and the narrow fluting in the spandrels at the right of the picture are typical of details best formed with wood molds. The bank of fluting at the left might be formed with wood or plaster molds. Venice High School, Venice, Calif.; Austin and Ashley, architects; Clinton Construction Co., contractor.

SECTION X

PLASTER WASTE MOLDS

Fig. 50—Elaborate detail such as this, whether the same motif is repeated or the ornament is used only once, is always formed with plaster waste molds. Entrance to Wilshire Professional Building, Los Angeles; A. E. Harvey, architect; L. T. Mayo, contractor.

Ornamental detail in architectural concrete involving floral designs, interlaced or pierced tracery, human forms, warped and intricately-curved surfaces is generally formed in plaster molds. Such molds are called "waste molds" because they are broken when stripping and can be used only once. The molds are made of casting plaster containing jute fiber and are reinforced and braced to prevent breakage. The type of detail which must be formed with waste molds is shown in Figs. 50 and 51.

The procedure for making waste molds depends upon the detail of the ornament. A model is first made in wood, plaster, clay or some other material. The model is made as a "positive" having the same shape as the finished concrete. From this model, "negative" waste molds, which are the reverse of the finished concrete, may be cast directly, or intermediate steps may be necessary, depending on the number of waste molds to be made and the detail of the ornament. The making of waste molds is almost always done by an ornamental plasterer, the methods used being similar to those employed in staff or fibrous plaster work.

The contractor and ornamental plasterer should consult regarding the details of the waste molds, to be sure they can be erected easily and are properly braced and reinforced to resist the pressure of the concrete. The molds must be made in sections that can be handled easily. If too heavy they are apt to be broken in handling. Individual pieces should not weigh over 150 lb. to be set without difficulty by two men.

The thickness of molds will depend upon the detail, but should not be less than 1 in. at any place. Jute

Fig. 51—Panels involving human figures are formed with plaster molds which are modeled the same as a piece of sculpture. Entrance motif Exposition Park, Los Angeles; Parkinson and Parkinson, architects; B. Mako, sculptor.

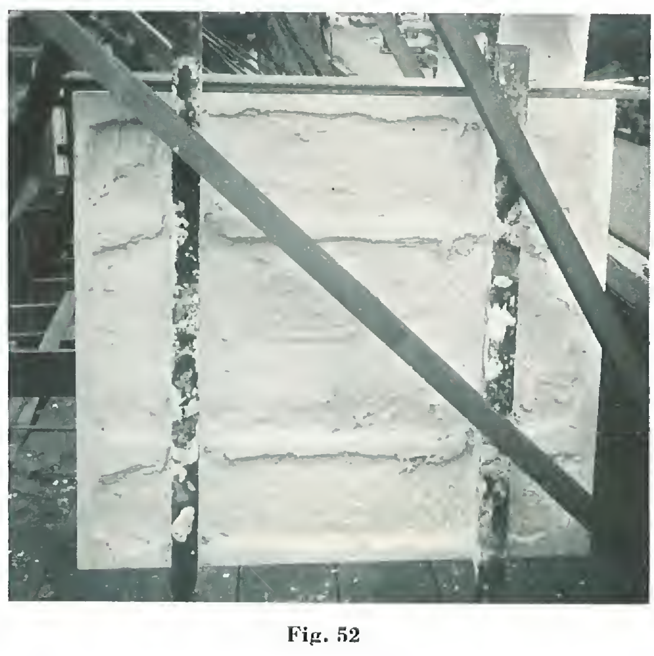


Fig. 52

fiber is added to the plaster to give it strength, but the mold-maker should be warned against using more fiber than necessary to give the plaster the required strength for handling, because an excessive amount of fiber makes it very difficult to chip the mold from the concrete.

The shape of the back of the mold depends upon the detail of the finished concrete. For flat surfaces without deep ornamentation, the back-side should be made flat to bear directly against the studs or wales. Fig. 52 shows the back of a waste mold used to form a recessed ornament. Note the flat surface around the edge of the mold and the two flat strips across the back. The flat surfaces are made to bear against the form sheathing or a framework of studs. The two wood strips are provided for handling the mold and are removed before it is set in position. The mold is nailed to the supporting timbers with common nails. The nail-heads are countersunk and the holes are pointed with patching plaster.

Irregular-shaped molds, or those with very deep relief (see Fig. 53), would be too heavy if made flat on the back, so the back is made to conform approximately to the shape of the front, with the thickness of plaster seldom more than $1\frac{1}{2}$ or 2 inches. Wads of plaster with a liberal amount of jute are used to reinforce the model and to block it out to a bearing against the form framing. In addition to the plaster wads or pads, a wooden frame consisting of 2x2-in. or 2x3-in. pieces to reinforce the mold is attached to the back with plaster and fiber as shown in Fig. 54. The face or contact-side of a waste mold like that shown in Fig. 54 is illustrated in Fig. 55a. Waste molds are usually delivered to the job ready to be assembled in the forms, and the various pieces fit together quite accurately. Slight irregularities may be removed with plane, chisel or steel wool. The ornament formed by the waste mold in Fig. 55a is shown in Fig. 55b.

The molds for irregular detail, especially where there are undercuts, are often made in several pieces. The

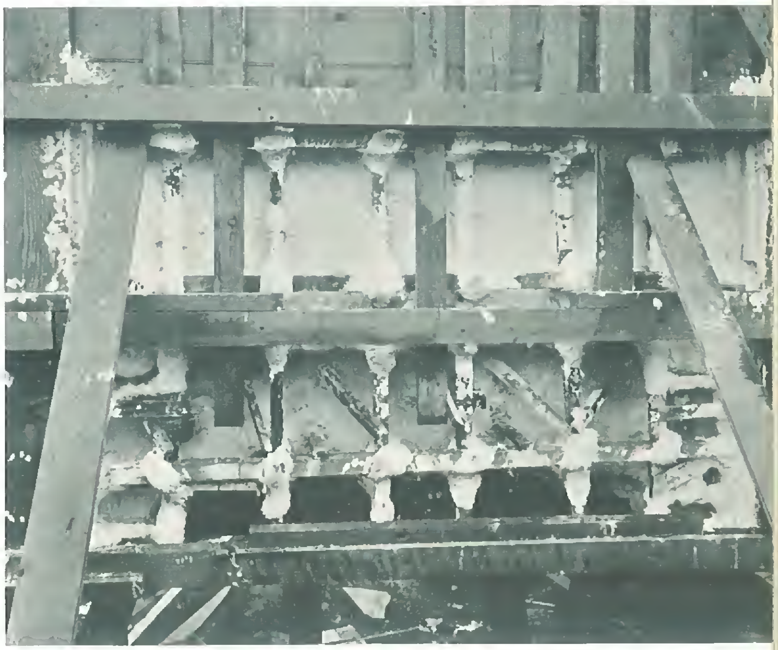


Fig. 54

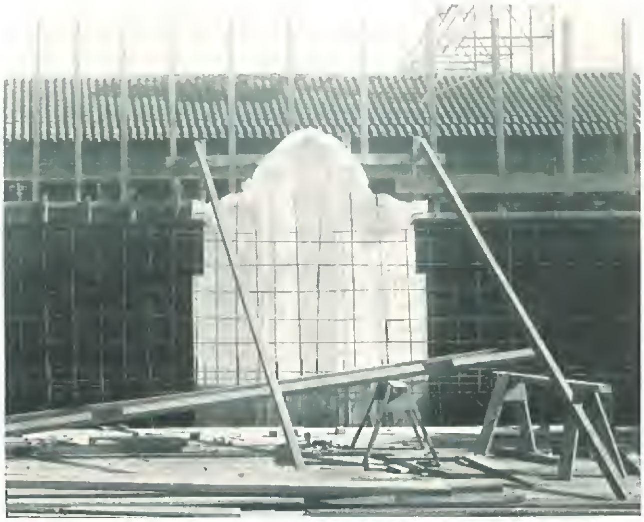


Fig. 53

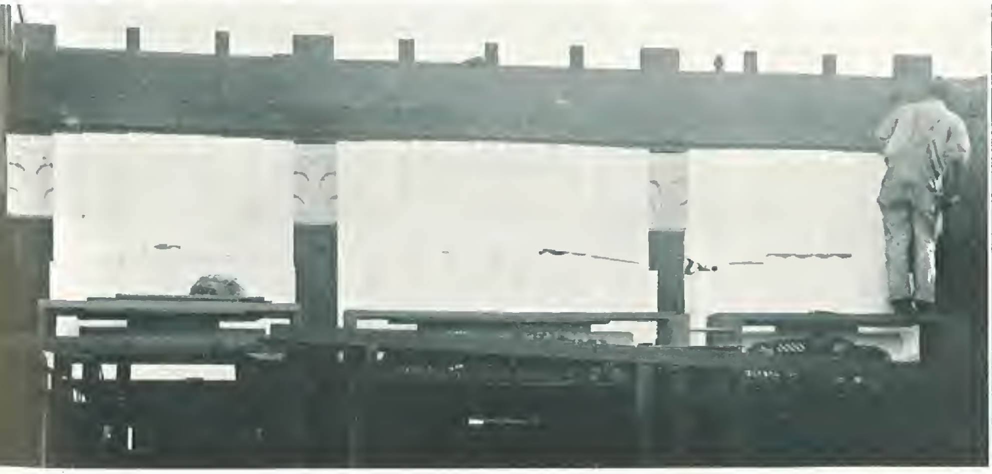


Fig. 55a

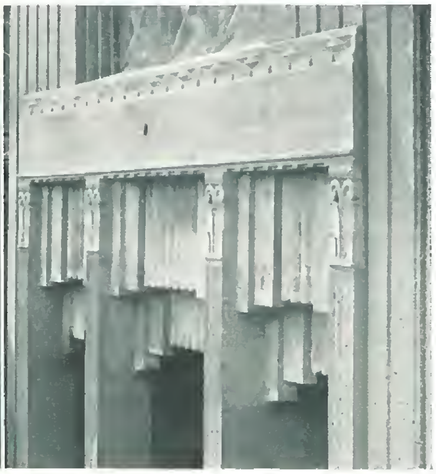


Fig. 55b

setting and bracing of such molds is simplified if the reinforcing frame for the various pieces is built out to a common plane. A plane parallel to the line of the wall is convenient because the framework of the molds can bear directly against and be tied to the studs and wales. Fig. 56 shows the mold for an ornamental head jamb of a door opening. The mold is made with a flat section parallel to the wall which bears against the studs. Jute fiber dipped in plaster is twisted about the studs and blocking to secure the mold in place.

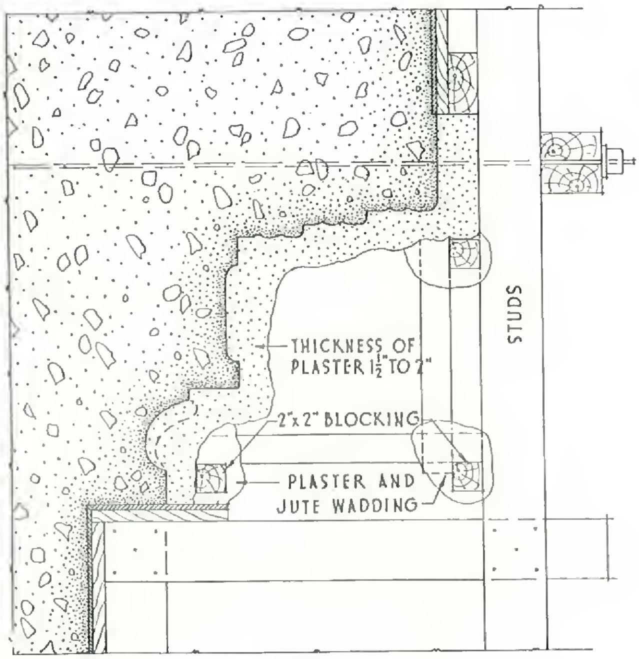


Fig. 56

Very small waste molds are not shaped on the back to conform to the face. It is evident from Fig. 57 that considerable labor would be necessary to block out from the back of such a small mold to a bearing against the form sheathing or studs, if the back conformed to the shape of the face. By making the mold with a smooth back and seat, it can easily be set in the form as illustrated. Such molds can be fastened in place by nailing from the face into the form sheathing or preferably from the back-side with double-headed nails. When the forms are stripped, the double-headed nails may be pulled and the waste mold will be left in place to protect the ornament until the rest of the forms are removed and other work in that area is completed. This illustration shows the importance of detailing forms before waste molds are made, so that the latter can be made to fit the backing prepared

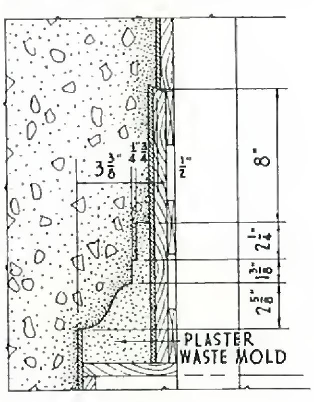


Fig. 57

Fig. 58

for them. If the waste mold-maker is allowed to devise his own details, troublesome blocking out and cutting of the backing for the molds is often necessary.

It is frequently necessary to chip the plaster from waste mold formed detail, particularly if there are undercuts or interlacing detail. For this reason it is desirable to use colored plaster for a thickness of about ¼ in. at the contact surface, the color serving as a warning to exercise care to avoid injuring the concrete. Fig. 58 shows a waste mold formed ornament. At the left of the opening the mold is still in place, while at the right side most of the plaster has been chipped away. Some plaster still remains in the undercuts, indicating the desirability of having a colored layer of plaster next to the concrete, since the plaster does not break away clean in one piece, but must be carefully chipped from around the concrete.

The smooth finish of cast plaster is not always appropriate to the architectural treatment, especially where it would make a surface too smooth in contrast to the surrounding texture formed with rough boards. To avoid this, the surface of waste molds or the model can be tooled or roughened with a wire brush.

It is important that waste molds be held rigidly in position. Wires can be passed through the face of the mold and by twisting the wire, the loop will bite into the plaster enough to bury itself. Two holes to receive the wire, generally 14-gauge, are drilled about 2 in. apart using a twist-drill just slightly larger than the wire. The cut made in the face of the mold when pointed with patching plaster will leave no trace of the wire. To further secure waste molds rigidly against the supporting studs and wales, jute dipped in plaster

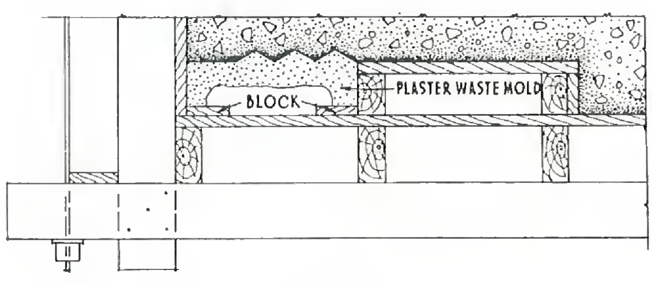


Fig. 59

is twisted about the framework of the mold and the supporting timbers.

In order to make the joint between a waste mold formed area and the adjoining forms as inconspicuous as possible, it is desirable to make the joining at a slight reveal or angle in the form as illustrated in Fig. 59. The natural line in the detail obscures any slight irregularity in the joint. Sometimes the architectural detail requires that the joining must be made on a flat surface. If so, the waste mold should be rabbetted to receive the abutting sheathing. (See Fig. 60. Observe that the waste mold is rabbetted at the corner when made in pieces.)

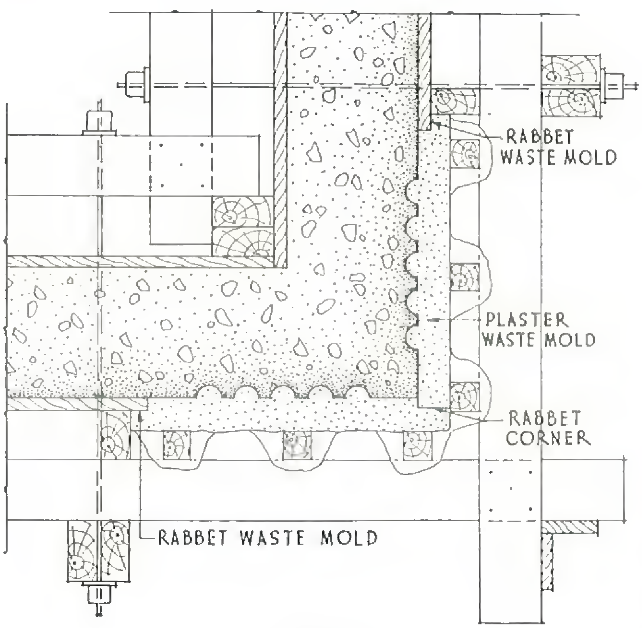


Fig. 60

After the molds have been secured in position and the forms are aligned and braced, all joints in the mold and between the mold and the adjoining forms must be pointed with Rutland Patching Plaster, U. S. Gypsum Cold Water Putty, Savogran Crack Filler or similar non-shrinking pointing compounds. These materials are used by mixing with a small quantity of water until plastic. The mixture is then pressed into the joints and smoothed off with a putty knife. When hard, fine steel wool or fine sandpaper is used to remove any slight roughness.

Waste molds are usually given two coats of shellac at the shop to make them waterproof and non-absorbent. If this is not done, there is quite certain to be a difference in the color of the concrete as compared with the adjoining areas. After the molds are set in the forms and all patching and pointing has been done, any new plaster is shellacked. Before concrete is placed, the waste molds must be greased to facilitate stripping. This subject will be discussed in a later section.

SECTION XI

METAL FORMS AND MOLDS

Metal forms and molds are used to a limited extent for architectural concrete work. Quite pronounced joint lines in a regular pattern are characteristic of metal panel forms and such joints are generally objectionable in an architectural concrete job. If the walls are to be stuccoed or the surface is to be ground, thereby covering or removing the joint lines, metal forms may be used. As a rule, however, the difficulties involved in working to window openings, floor heights and corners with standard or even special panels offset any possible economy resulting from re-use of material and the labor saved in erection of straight wall forms. Fig. 61 shows the pattern effect produced with metal forms. At the right is shown the result of using special panels to work to a corner. The wall illustrated is below grade, but the effect obtained is characteristic of a metal form constructed wall which is not satisfactory where the concrete is exposed.

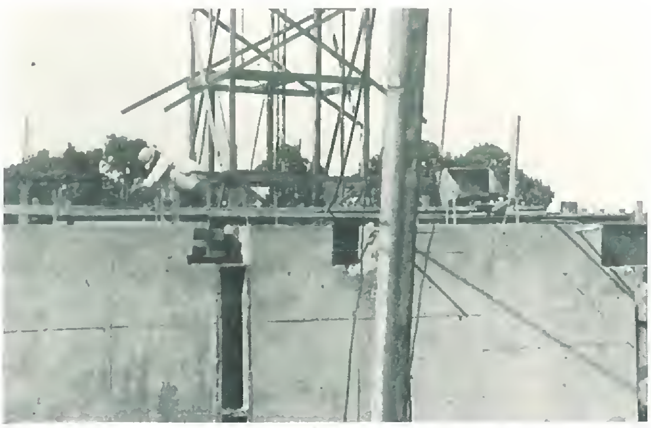


Fig. 61

Special metal molds have their place among architectural concrete forms. Black iron should preferably be used for this purpose, because galvanized metal may stick to the concrete, leaving it rough even though the forms are well oiled. Corrugated iron sheets are quite frequently used, for example, to form fluting in pilasters, piers and spandrels. The sheets are made with standard corrugations, or special corrugations can be had if the quantity of material required is sufficient to warrant special rolls. Other special shapes may be used economically and satisfactorily if there are a large number of repetitions. As a rule, plaster molds and sometimes wood molds can be used for any detail that can be formed with metal. Metal molds are more difficult to erect than those of wood or plaster, but the added labor and time required may be offset by a saving of material if there is considerable repetition. The choice of metal molds as compared with other types is generally a question of economy.

Fig. 62—Metal molds were used to advantage in the forming of the curved surfaces of the mullions in this building and for the fluting at the top of the tower. Wilshire Tower Building, Los Angeles; Gilbert Stanley Underwood, architect; H. W. Baum Co., contractor.

A typical example of a job in which metal molds were used is illustrated in Fig. 62. The mullions involve two curved surfaces as shown in Fig. 63a while the corner piers at the top of the tower are made up of five flutes as shown in section in Fig. 63b. The curved surfaces in this job were so detailed that standard rolls could be used for shaping the sheet metal forms thus eliminating the cost of special rolls. The sheet metal is stiffened by blocks of wood or collars cut on a band saw to fit the shape of the mold. The blocks or collars should not be spaced more than 9 in. to 1 ft. apart to prevent distortion of the metal. The gauge of metal used will depend upon the size of the mold but, ordinarily, 24 or 26-gauge is satisfactory. Where possible, as in the mullion detail, it is desirable to lap the metal around a corner on the outside of the sheathing to prevent leakage and to avoid a streak on the surface of a slightly different texture that would result if the metal were nailed to the face-side of the forms.

It is essential that all sheet metal be cut in the shop on a shear to insure straight smooth edges. Corrugated sheets should be cut exactly at the center of a corrugation in order to make a tight joint between the metal and the backing to which it is nailed. By making the cut at the center of the corrugation, a full-width corrugation is obtained if it is necessary to join two sheets. The sheets should always be butted together at the joint and not lapped (see Fig. 64a).

The terminating vertical edges of corrugated sheets may be cut along the center of a corrugation the same as for a butt joint between sheets as shown at the right edge of the sheet in Fig. 64a. From an architectural standpoint, it is usually better to have a slight reveal where the corrugated surface joins the plain surface. This requires the use of a filler strip along the edge as shown at the left of Fig. 64a. The strip is milled to the shape of the corrugations.

When a single sheet is not long enough to make the entire form, and cross-joints are necessary, the sheets may be butted or, if desired, lapped about ½ in. as shown in Fig. 64b. The upper sheet is lapped over the lower one so the slight offset caused by the thick-

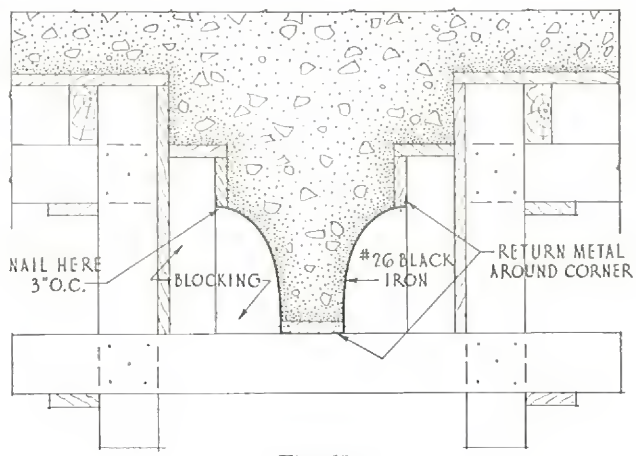


Fig. 63a

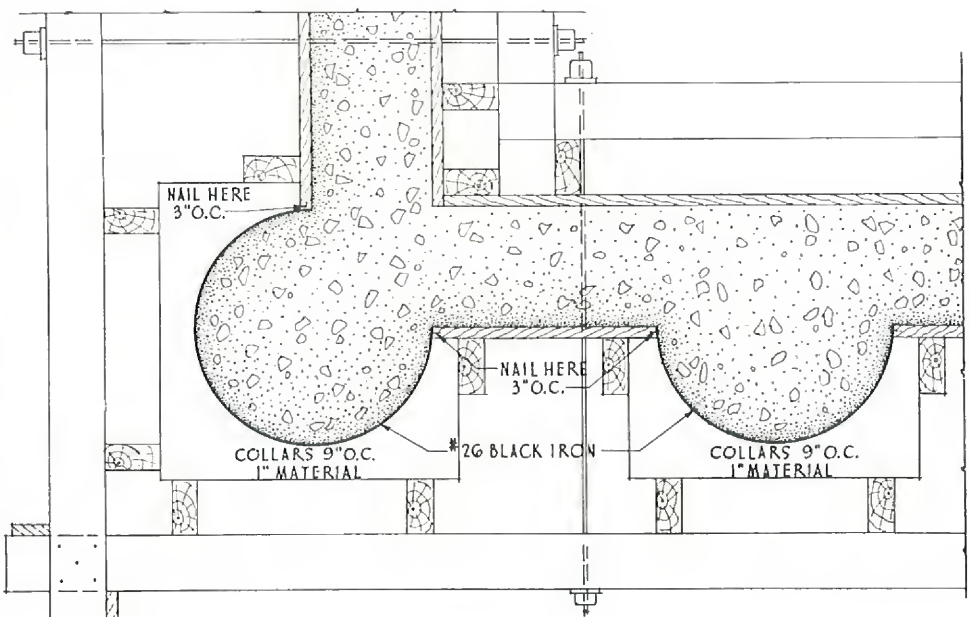


Fig. 63b

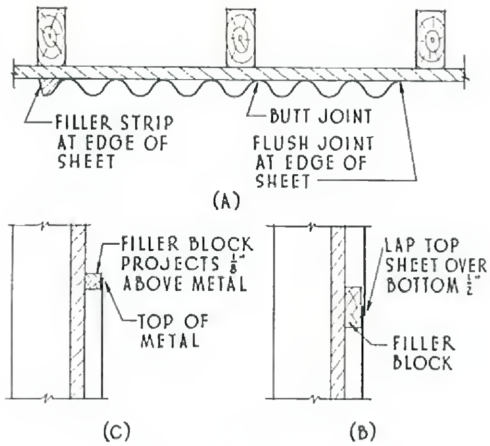


Fig. 64

ness of the overlapping metal will not cast a shadow, thereby making the joint less conspicuous. Short wood blocks shaped to fit the corrugations placed behind the lapped joint will furnish a solid support to which the edges of the metal can be nailed.

Both ends of a corrugated metal sheet should not bear tightly against finished concrete surfaces, otherwise it cannot be removed without damaging the concrete. The blocking used to close the ends of the form should fit the corrugation snugly and should project ⅛ in. above the metal as illustrated in Fig. 64c. This will prevent the end of the sheet being embedded in the concrete and will facilitate stripping.

Metal sheets of any kind used as a form liner over a wood backing must be nailed at frequent intervals to prevent slight bulges. Four-penny box nails should be spaced about 6 in. apart along all edges and not more than 12 in. horizontally and 24 in. vertically throughout the area of the sheet.

Fig. 65

SECTION XII—TYPICAL FORMS

Straight Walls

Straight wall forms for architectural concrete work present a few problems not encountered in ordinary structural concrete work. It is primarily important to remember that the concrete surface is the finished surface which is to be left exposed. Care must be exercised at all times in constructing forms to insure perfection of corners, alignment, texture and detail.

When starting the construction of wall forms, a plate should be nailed to the footing; it is important that the plate be carefully lined, as the straightness of the wall will depend upon good alignment of the starting plate. This plate is set out from the finished face of the wall the thickness of the form sheathing. Studs are set on the plate and lightly nailed to secure them in place. A 1x4 ribbon nailed to the studs will serve to align them temporarily. Braces at 10 to 12-ft. intervals are, of course, carried to the ground or some other place where they can be secured. The bottom sheathing board must be leveled accurately. Since the footing will not always be truly level or smooth, it will often be necessary to fill out below the first full sheathing board to make a tight joint at the bottom. It is not desirable to attempt to shape the bottom board to conform to the irregularities of the footing.

An example of a special case, but one which illustrates the general principles of the starting of a wall form, is shown in Fig. 65. In this instance a rustication was located at the water table. The strip used to form the rustication serves also as the plate on which the studs for the outside forms were erected. A level starting base was thus provided. One row of sheathing was placed at the bottom which served as the ribbon to hold the studs in line. The frame was temporarily braced to the ground and brought to final alignment after the sheathing was all applied.

Sheathing lumber even when dressed and matched is not always quite uniform in width. This may cause the joint lines to get out of level; likewise, irregularities in driving up adjoining boards may aggravate this condition. It is therefore necessary to check the level of joint lines at frequent intervals. To do this, lines of levels may be set at 3 or 4-ft. intervals vertically. The lines can be marked on the studs about every 10 ft. horizontally, which should be close enough together for the carpenters to follow. It is also convenient to mark off a stick into divisions equal to the width of the sheathing to be used in checking the level of the joint lines as the building of the forms progresses.

Accurate alignment of architectural concrete forms is absolutely necessary. Any amount of care exercised in securing good alignment is time well spent. One method for aligning a long section of forms is to set points on the floor with a transit, the points being not more than 30 ft. apart. These points may be set back from the face of the wall 3 or 4 ft. to be well out of the way. Control-points at the top of the wall opposite

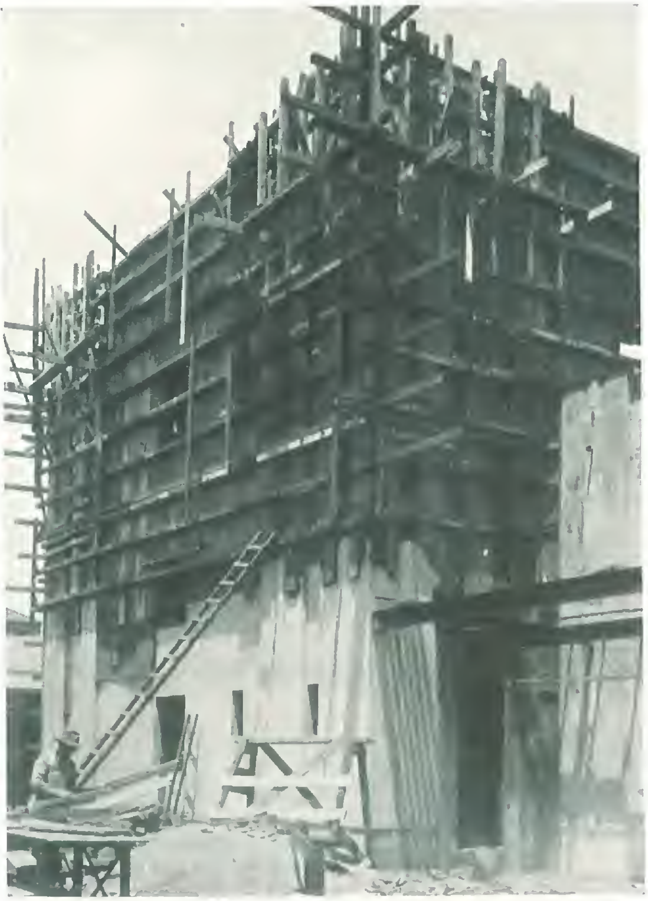


Fig. 66

the transit-points are then accurately set by plumbing up from the floor-points and measuring over to the wall. Intermediate points are set from a chalk-line strung between the control-points. Aligning of forms should be done only when there is little wind. If a favorable time cannot be chosen, then control-points set much closer together will aid in securing satisfactory alignment.

Sheathing is sometimes run vertically, if the form is to be lined with Presdwood or thin plywood, and occasionally for some special architectural effect. Fig. 66 is an illustration of such construction in which 4x4 timbers serve the purpose of both studs and wales. The tie bolts pass through the 4x4's. This method of form construction is not usually as economical as the more conventional type with studs and double wales and either vertical or horizontal sheathing. Drilling for bolt holes is avoided by using the double wales, which saves considerable labor. Slightly more lumber is required, but the additional cost of material is offset by the saving in labor. It is also easier to properly align a wall in which the sheathing boards, whether vertical or horizontal, are nailed to studs which, in turn, are supported by wales.

In Fig. 66 note the blocking out required for the waste molds at the top of the wall. This is necessary because the backs of the molds project beyond the face of the wall forms. Sometimes this is unavoidable, but if possible, the molds should be detailed to avoid blocking out.

Wall forms must be securely tied at the corners so they cannot move. A slight opening of a corner will cause bleeding that may result in sand streaks and will produce an irregular line and fin that cannot be satisfactorily removed or covered over. In order to make a corner tight, the wales should cross and strips should be located as shown in Fig. 67. Strip 1 prevents any

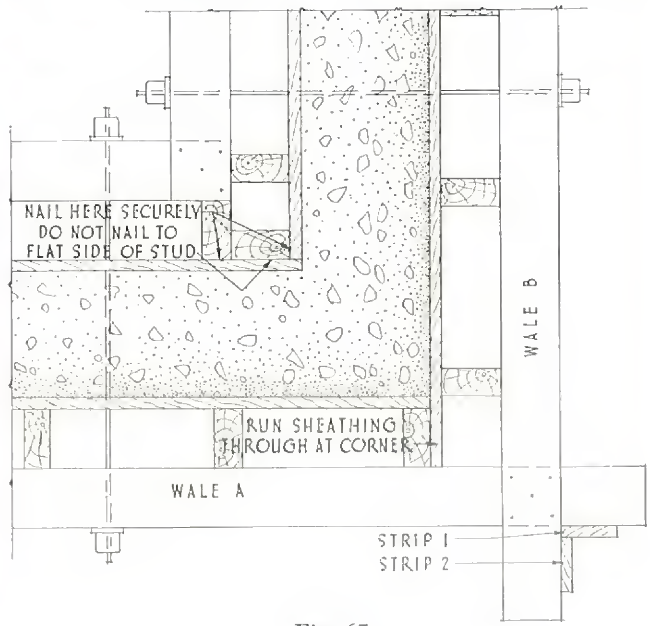


Fig. 67

outward movement of Wale *B* and Strip 2 holds Wale *A* securely in position. A properly secured corner is shown in Fig. 68. In this instance, the wales are on the same level so the top member of one wale and the bottom member of the other are cut off at the inter-

Fig. 68

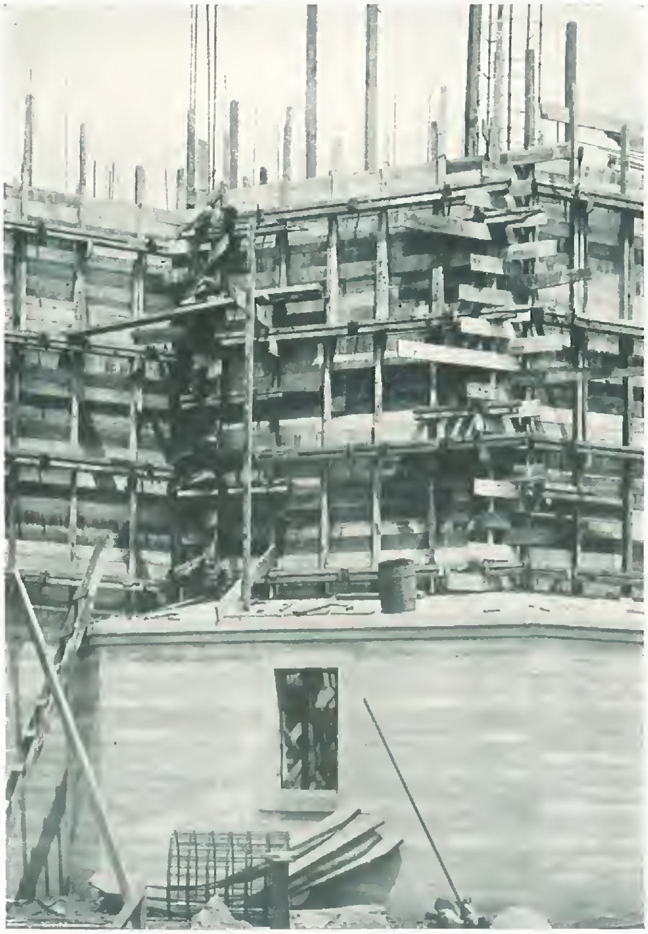


Fig. 69

section, while the others form the overlapping corner. Four kick-strips instead of two are required to secure a corner of this type.

Sometimes "log cabin" corners, such as illustrated in Fig. 69, are used and are satisfactory. The corner can be held tight by this method. Note the kick-strips in back of the interlaced sheathing boards which prevent any movement. This type of corner is more troublesome to build and more labor is required for both erection and stripping than for the corner shown in Fig. 68.

Round Corners

Rounded corners of radius greater than 4 ft. and curved walls can be formed with plywood applied directly to studs. Ordinary lumber can be used for curves having a radius of 18 or 20 ft. but seldom for those of shorter radii. The thickness of sheathing will

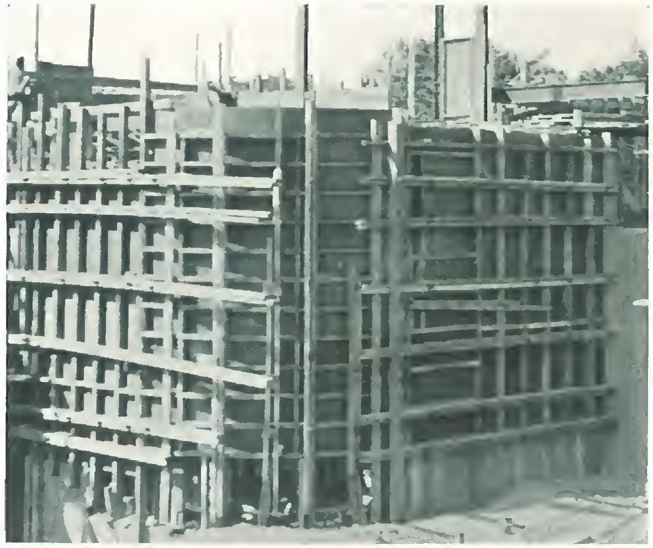


Fig. 71

depend upon the radius of the curve. As a rule, $\frac{1}{4}$-in. or $\frac{3}{8}$-in. plywood is used for curved corners. Corners having a radius less than 4 ft. are best formed by constructing a solid backing over which $\frac{1}{8}$-in. Presdwood is applied.

A typical detail of a form for a long-radius curve, not less than 20 ft., using plywood sheathing, is shown in Fig. 70. The studs are vertical and are blocked out from yokes or frames which are spaced 4 to 6 ft. apart vertically. By staggering the frames to break joints, a full circle or any part can be held rigid. Note that for the outside form it is necessary at the center of the frames and for a distance of two or three studs each way to tie the studs to the frames to prevent the spring of the sheathing from pulling it away from the frames. For the inside form it is necessary to tie the studs at the outer ends of the frame instead of those at the center.

A method of building a round corner form for a curve of 4-ft. or greater radius is shown in Fig. 71. Horizontal segmental ribs are spaced about 12 in.

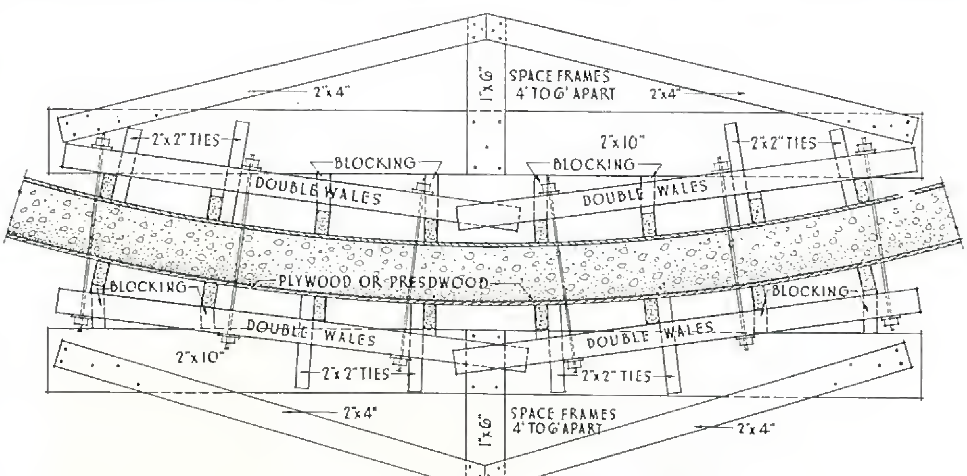


Fig. 70

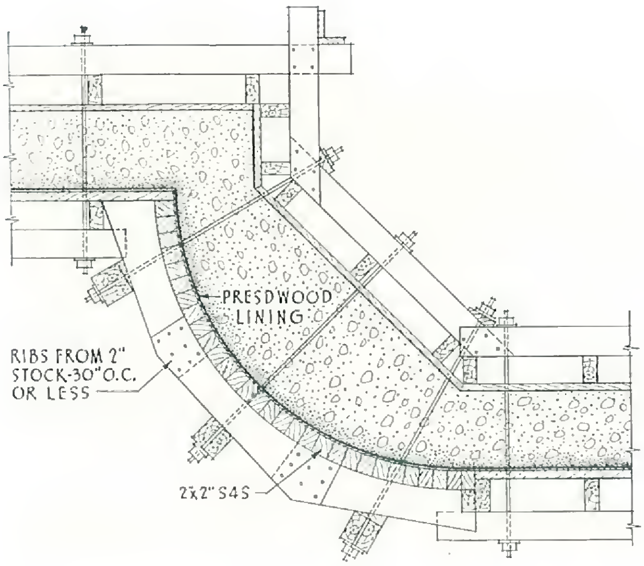


Fig. 72

apart. Quarter-inch plywood with the grain running vertically is applied to the ribs. At the vertical joints short pieces of 2x4, to which the edges of the plywood are nailed, are cut in between the ribs. The plywood is nailed at 6-in. intervals along the ribs.

A detail of a short-radius convex corner is shown in Fig. 72. Segmental yokes are cut from 2-in. material to the required curvature and then spaced about 30 in. apart. The backing for the ⅛-in. Presdwood lining is made of 2x2 dressed strips placed tightly together. While theoretically, a slight bevel would be necessary on each strip in order to make them fit snugly, the bevel is so very slight that ordinary square-edged lumber is satisfactory.

The spring of the Presdwood lining will tend to pull it away from the backing unless closely nailed. To be sure the lining holds securely, it should be nailed with cigar box nails at intervals of not more than 6 in. in each direction.

The forms for a concave corner do not differ materially, as is evident from Fig. 73. In either case, because of the radius of the corner, the last tie through the straight part of the wall at each side of the corner must be set back several feet. Even though the intersection of the wales is properly blocked as previously described, there might be sufficient deflection of the wales to permit the corners of the form to open slightly. It is therefore desirable to tie the corner with a piece of 1x4 as indicated in the illustration.

When the form is stripped, the side wall forms are first removed. This permits the circular form to be removed as a unit. Before the circular form is stripped, the pencil rod ties should be pulled from the concrete. To do this, cut the rods behind the outside wales and pull the rod toward the inside of the building with a rod-puller. There are two reasons for removing the ties before the form is stripped—the form protects the concrete against possible spalling and guides the rod; furthermore, if the rod is removed first, it will not interfere with removal of the circular form as a unit.

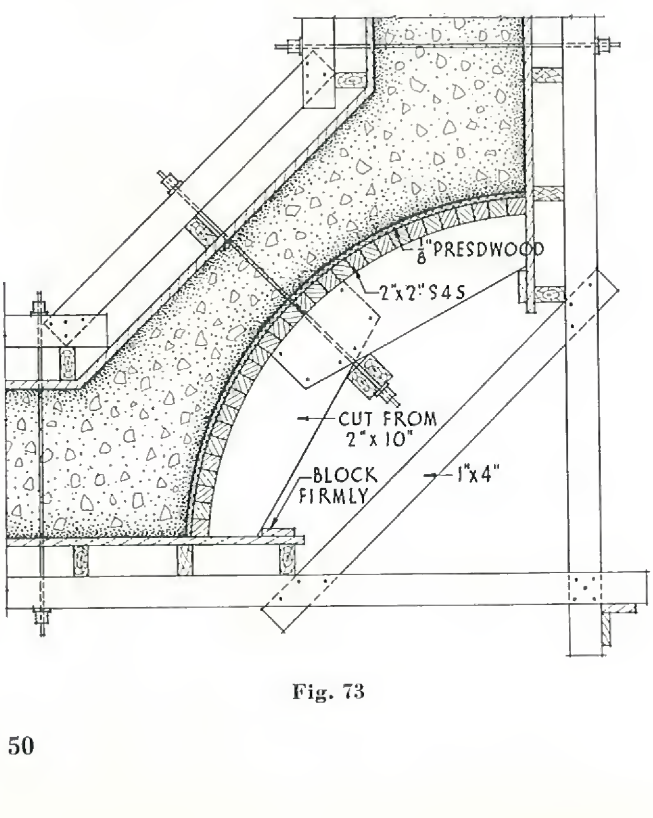


Fig. 73

Water Tables

In the majority of buildings there is usually a water table at or very close to the grade-line which projects slightly beyond the face of the wall above. A not uncommon detail for a water table, except for the rustication strips, is illustrated in Fig. 74. The studs from below the water table are carried above the offset so the studs for the upper part of the wall, which are set in, can be securely blocked and tied to the lower studs to make the form rigid. The lower studs may be in random lengths, so long as they lap the studs above by 18 to 24 inches.

A slightly different water table detail is shown in Fig. 75. The difference in slope of the two principal surfaces makes it necessary to use milled pieces for sheathing in order to produce a lap

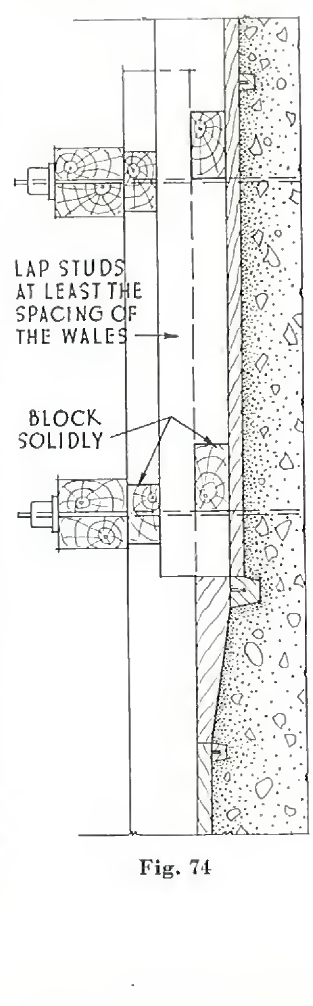


Fig. 74

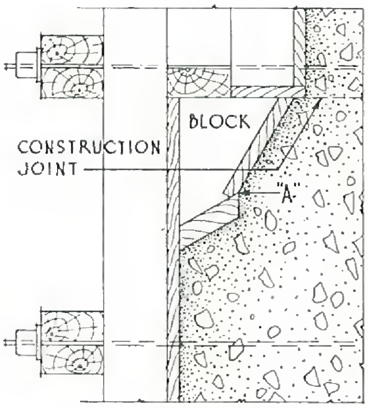


Fig. 75

at point *A*. It is undesirable to attempt to butt two pieces along such a line, as it will be almost impossible to make the joint tight enough to prevent leakage. The studs are lapped and blocked in the same manner as in the preceding example.

Water tables sometimes involve shapes not conveniently nor desirably made entirely with wood forms. The detail shown in Fig. 76 is of this type. Because of the undercut in the profile, the swelling of a wood mold might break the concrete before it had thoroughly hardened. A plaster mold, which does not swell, for the upper part of the detail combined with stock lumber for the lower part makes the most satisfactory form.

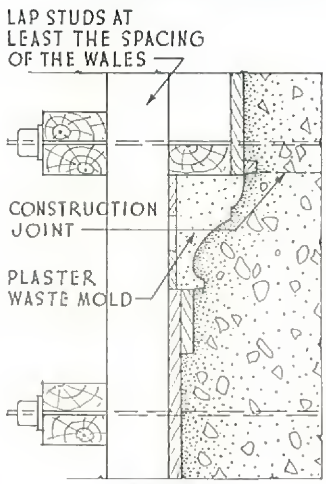


Fig. 76

Pilasters and Piers

The forming of pilasters and piers, and often window mullions and reveals, presents somewhat similar problems. Generally, the face form for a pilaster or pier can be made as a panel, regardless of the form material used. Accuracy in the forming of the corners is important, as such details are usually a focus of attention in the facade of a building. The principal point of observation is generally from a position in front of the building; so all corners must be straight and true and there should be no impression in the concrete of the end-grain of the form boards visible when the building is viewed from in front.

Fig. 77 is a typical detail for a pilaster having a projection greater than the depth of the studs. The sheathing forming the face should always lap over the corner, while the boards forming the reveal butt against the face sheathing. Likewise, the main wall sheathing should butt against the reveal, and the sheathing forming the reveal should butt against the main wall sheathing. In this way, the marking due to end-grain of the form boards or the edge of plywood will be on the side of the reveal and not visible from in front. Furthermore, if a very slight fin is formed at the outer edge of the pilaster, light rubbing with a carborundum stone will remove the fin and the surface will not appear marred. Of course, this is only true when there is very little leakage. Appreciable leakage should be avoided by making the corner as tight as possible. Note that the blocks between the main wall wales and the wales across the pilaster are made slightly smaller than the spacing they are to fill. When the ties are tightened, there will then be no tendency to ride on these outer blocks and the joints *A* and *B* will be held tight. The sheathing forming the reveal should be tacked very lightly to the flat side of the stud in the corner. If sheathing is nailed from two directions onto a stud, it is very difficult to strip the forms without tearing the stud to pieces.

A very shallow pilaster is illustrated in Fig. 78. In this case, the projection is only the thickness of the

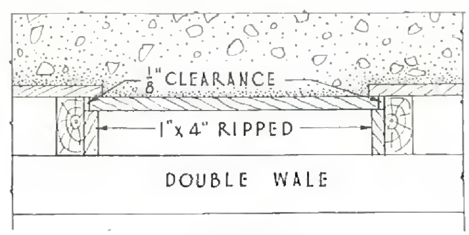


Fig. 78

sheathing lumber. In order that the wales may extend past the pilaster, which is desirable since better alignment and security of the forms are obtained, 1x4's ripped to a width equal to the width of the 2x4 studs less the thickness of the sheathing are nailed with double-headed nails to the studs to support the sheathing for the face of the pilaster. This sheathing, whether

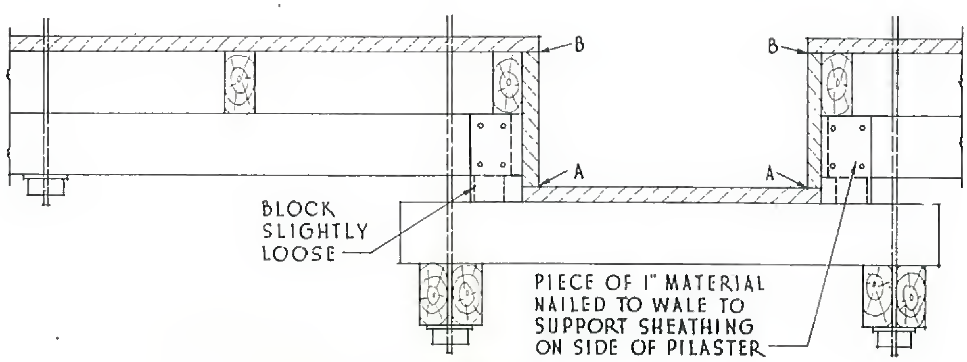


Fig. 77

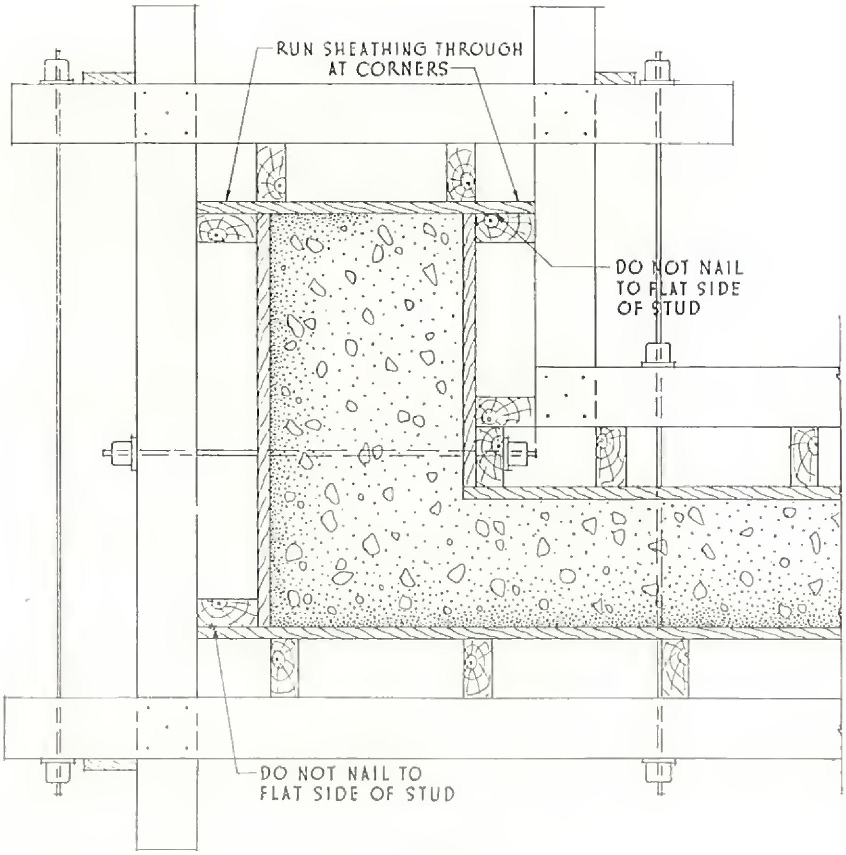


Fig. 79

It is sometimes difficult to strip the forms adjacent to deep reveals, due to swelling of the lumber which causes it to freeze against the concrete. Under such conditions, stripping will be facilitated by forming the reveals with a draw of about ¼-inch. It is also desirable, if the sheathing against the reveal is assembled with the main form to be removed as a single panel, to use vertical-grain lumber against the reveal rather than flat or slash-grain material. The latter will swell slightly and tends to bite into the concrete.

made up in a panel or erected in place, should not bear against the 2x4 studs at each side. By allowing a little clearance, stripping is made easier, and the face form may be stripped before the adjoining studs.

A typical form detail for a deep reveal involving the principles discussed in regard to deep pilasters is shown in Fig. 79.

In the pilaster shown in Fig. 80, it was desired to carry the horizontal form board marking of the main wall areas continuously across the pilasters. This necessitates the use of short pieces of sheathing with the studs running vertically. Since the offsets in the pilaster are just the thickness of the sheathing, the studs are simply blocked out from the walers with pieces of sheathing boards to take up the offsets. When the blocking behind the studs requires a piece 2 in. or more in thickness, it is advisable to use larger studs to eliminate blocking. If there is considerable repetition of the same detail throughout the job, it will pay to rip larger studs to fit the offsets, thus avoiding blocking.

Spandrels

Spandrels are often decorative features of a building. Sometimes they are quite highly ornamented and require the use of plaster waste molds as forms. In general, however, regardless of the ornamentation, the method of forming all types of spandrels is essentially the same. The most common spandrels project partly above and partly below the floor slab. It is convenient to locate a construction joint at the top of the floor as this simplifies the placing of concrete, providing the structural design of the spandrel will permit a joint at the floor-line. When a joint is so located, it is desirable to use some architectural detail at that level to obscure the joint. If there is no architectural detail at that level, then the entire spandrel should be placed with the floor slab so as not to have a joint cut directly across the face of the spandrel.

If there is a joint at the floor-level, the forms for the upper part of the spandrel are not erected until the floor

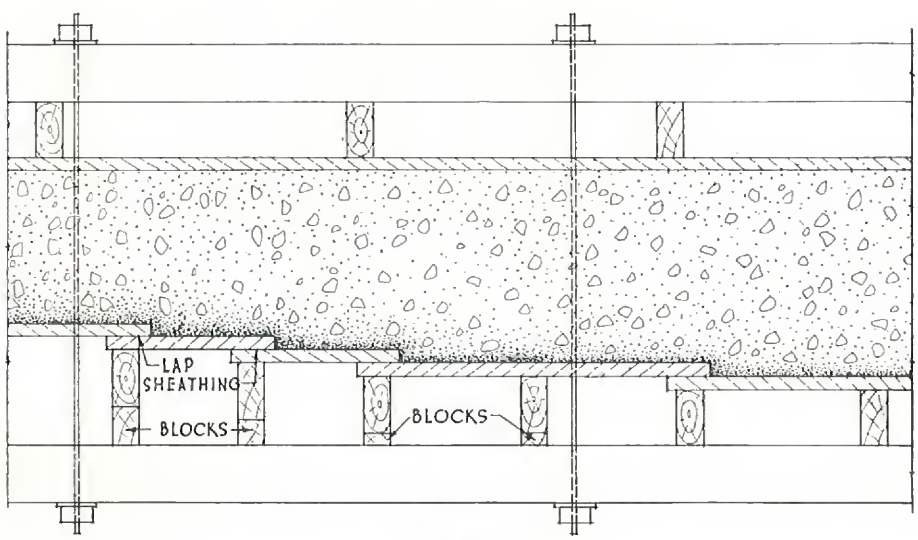


Fig. 80

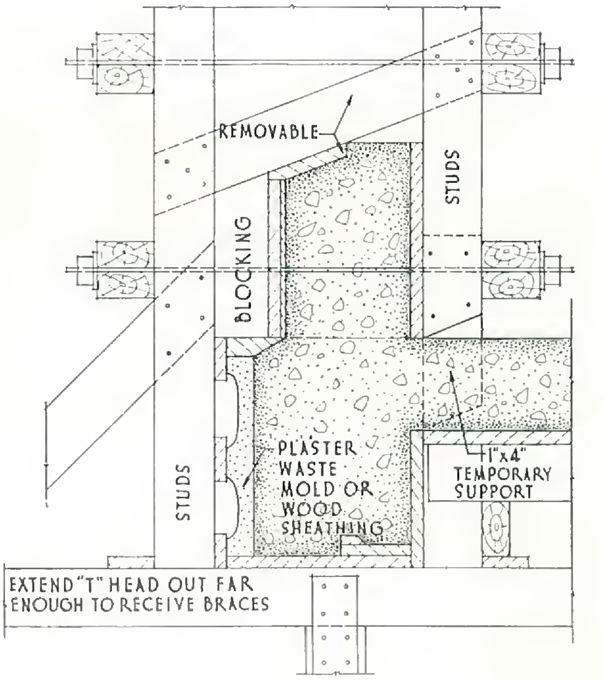


Fig. 81

concrete has been placed. The form shown in Fig. 81 is satisfactory, whether the upper and lower parts of the spandrel are constructed separately or in one operation. Braces from the extended T-head are used to hold the forms in alignment rather than wires

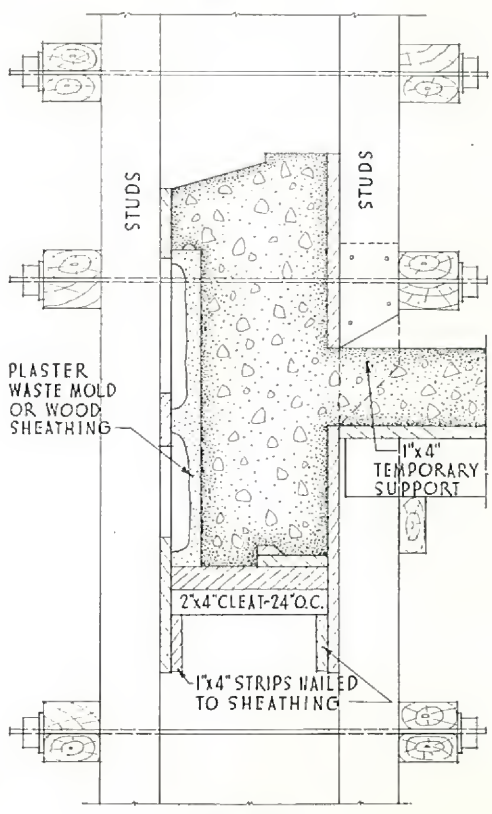


Fig. 82

holding the forms back to the floor slab deck as is sometimes done. The latter method is not so positive in its action. If, for some reason, wires must be used, they should be fastened to the outside form high enough above the floor to pass over the top of the spandrel so they will not be embedded in the face of the wall.

In order to support the inside form, pieces of 1x4 are nailed to occasional studs and rest on the slab forms. These supports are removed as soon as the concrete in the spandrel and slab has been placed.

Fig. 82 shows a slightly different method of construction in that the T-head and diagonal-braces are not used. When it is possible to extend the studs past an opening and to let the sheathing project at least part way across the opening to receive the forms for the window as illustrated, the weight and pressure of the concrete is transmitted directly to the studs, making other braces and shores unnecessary.

Windows

The forms for window openings must be made rigid and substantial to prevent distortion under the pressure of the concrete. The box forming a window opening is best made of 2-in. material, as it is much less apt to get out of shape than one made of thinner material and the sash will fit properly. Strips *A* and *B* (shown in Fig. 83) required to form the recess to receive the sash, are securely nailed to the 2-in. plank forming the frame. The cleats should be not more than 24 in. apart. If less than 2-in. material is used, then a closer spacing will be necessary. Cross-braces should be located at each cleat horizontally and vertically unless there is an inner frame of 2x4's as illustrated in Fig. 84. The frame is supported in the form by nailing to the form sheathing.

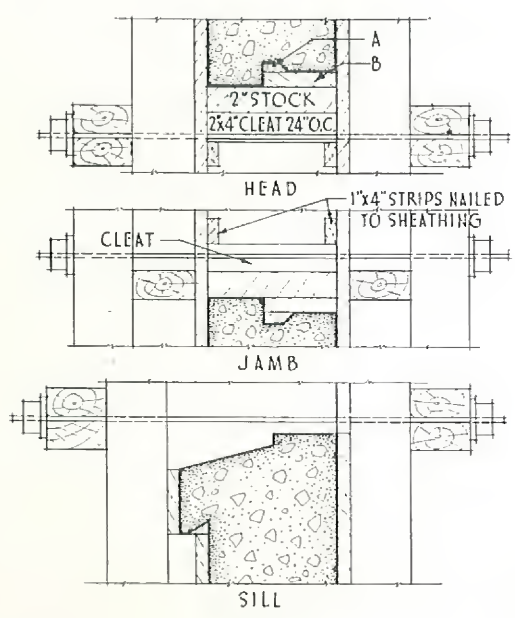


Fig. 83

Fig. 84

Fig. 85

Except for windows with very steep sills, it is necessary to be able to get at the sill in order to finish it and to properly work the concrete into place. For these reasons, the sill of the form may be omitted altogether, as indicated, or the sill-piece made in two sections for easy removal.

A circular window-head which is formed in the same manner as a rounded wall corner is shown in Fig. 85. Segmental ribs are cut to the desired curvature. Strips cut from 1x2 or 2x2 stock are applied to the ribs and then plywood or Presdwood is nailed to this solid backing. The sides of the forms are the same as for a rectangular opening.

To strip a window form, the cross-braces are first knocked out. The vertical kick-strips against which the cleats bear should then be removed. Next, take off the top and bottom cleats and wedge out the head, using wooden wedges. Do not pry the form loose with a pinch bar, for this is certain to spall the concrete. The wooden wedges should be driven in at one end, forcing it down and away from the side member. A 45° cut or miter through the sides of the frame is sometimes made when the form is built to facilitate stripping.

Occasionally the permanent window frames are set in the forms. Fig. 86 is an illustration of such construction. A small, removable strip around the frame on the outside is necessary in order to make a space for caulking. In the illustration, an I-beam or channel, laid flat, supports the window frames, the steel shape being supported by hangers from the concrete lintel

Fig. 86

above. In general, the practice of setting the permanent frames in the forms is not recommended, because they are so likely to be distorted, causing the sash to work badly.

Doorways

The forms for door openings do not differ materially from those for windows. Because the openings are generally larger, somewhat more attention should be given to bracing and tying of the forms to prevent any distortion. Unless the opening is extremely wide, it is best to run the wales across the opening. By so doing, the forms can be kept in better alignment and any tendency of the frame to twist can be prevented. Workmanlike joining of all angles is especially essential in doorways because they are important points of interest in the architectural treatment of the building.

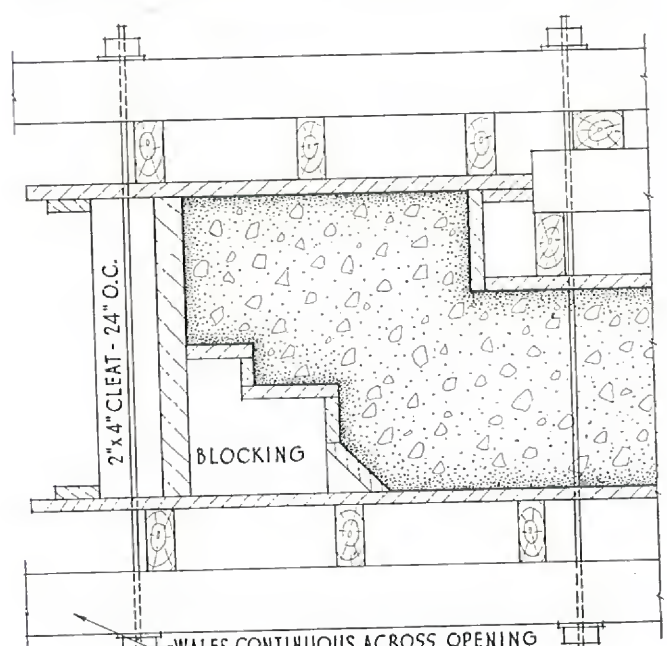


Fig. 87

A typical method of forming a common entrance detail is illustrated in Fig. 87. The doorway is recessed by several small reveals which may or may not be continuous across the head of the opening. The similarity of the form to that for a window opening is apparent. A substantial frame is made with 2-in. plank cleated with 2x4's at 24-in. centers. The kick-strips in back of the cleats are nailed securely to the sheathing and the whole frame is rigidly cross-braced. The form for the reveal is built up as a box and set into the angle between the frame and the outside wall form. A row of ties is placed just inside the opening to hold all joints tightly together.

There are often deep reveals at doorways and the total width of the opening may be too wide to warrant or to be practical to carry the wales across the opening. A doorway reveal involving a fluted surface is shown in Fig. 88. An unornamented surface or an elaborate detail requiring the use of plaster waste molds may be substituted for the fluting shown. The fluting is formed with milled wood pieces which are securely nailed to blocking so that the panel can be erected in one unit and removed as a unit after the straight wall forms have been stripped. Of course, this is not essential unless the same detail is to be repeated elsewhere in the building or the entrance is so high as to require more than one lift of forms. Note that the blocking to which the fluting forms are attached is backed up by horizontal studs which serve also to tie the main wales together, thus preventing any movement of the corner due to deflection of the wales which extend quite a distance beyond the last ties. The forms for the door opening proper would be made essentially the same as shown in Fig. 87.

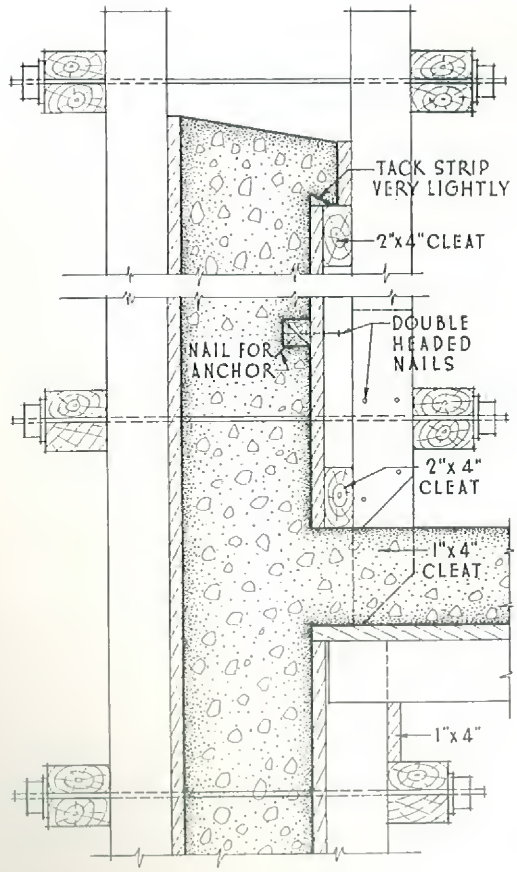


Fig. 89

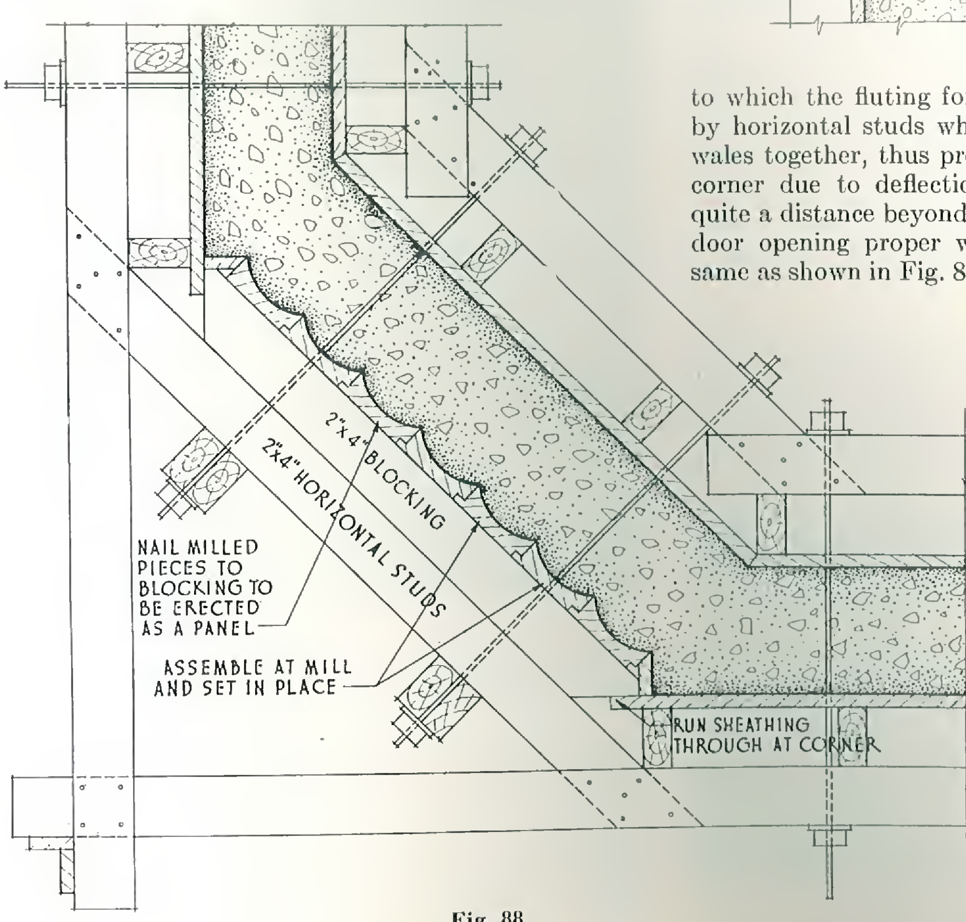


Fig. 88

Parapets

Usually the forms for the inside of a parapet wall are made in panels which are erected as a unit. Panels 10 to 12 ft. long are convenient for the average job. In order to support the back form until the roof slab concrete is placed, two 1x4 pieces for each panel are nailed to the studs and rest on the roof slab form as shown in Fig. 89. These supports are pointed to facilitate removal, which is done before the concrete has hardened. Double-headed nails are used to fasten the 1x4 pieces to the studs.

Where there is an overhanging drip, it is practically impossible to construct the panel for the back of a parapet so it can be removed as a unit. The form bears against the roof at the bottom and the drip at the top; so swelling of the lumber causes it to bind. When stripping, the 2x4 cleats are removed first. In order to do this readily, the sheathing lumber is nailed rather lightly. Having removed the cleats, stripping of the sheathing is started at the bottom so as to loosen the upper boards and prevent spalling the lip of the drip. The reglet is formed with two triangular strips as shown. A nail is driven into the lower strip to extend into the concrete for anchorage. This strip remains in the concrete after the forms are removed. The upper and lower strips are both secured to the forms by means of double-headed nails. These nails are pulled before the form sheathing is removed, leaving both strips in the concrete temporarily. After the top strip has dried sufficiently to shrink it slightly, it can be removed without danger of spalling the concrete.

SECTION XIII

ERECTING—OILING—STRIPPING

In the preceding sections, considerable has been said regarding the operations of erecting, oiling and stripping forms, particularly as applied to certain specific forms and materials. There are, however, some general principles pertaining to the construction of architectural concrete forms which are so important that they will be discussed in more detail in this chapter. Some repetition is also warranted because the quality of the job is largely dependent upon the care exercised and methods used in erecting, oiling and stripping the forms.

Erecting

Too great emphasis can not be placed upon good craftsmanship. Angles and joints in forms must be made accurately so that corners will be sharp and straight. Leakage through the forms must be prevented or there will be fins along joint lines and corners. Miters that are not quite tight and joints between plywood or Presdwood sheets that are open enough to allow any leakage should be pointed with patching plaster or similar material. Fig. 90 shows a carefully erected form in which the joints have been filled with patching plaster wherever needed. Any surplus plaster is cleaned off with sandpaper.

Fig. 90

There are some places where it is difficult to draw a form tight simply with the tie rods, wales and braces. A liberal use of wooden wedges driven between blocking and the form sheathing will often serve to hold joints tightly against the pressure of the concrete. Fig. 91 is a good illustration of the use of wedges. The corner is well tied and braced and any small amount of play between the sheathing and the blocking is taken up with wedges. Note that double-headed nails are used to make stripping easier.

Fig. 91

Studs, wales and ties must be placed close enough to prevent bulging of the forms. Make the mistake, if it can be called such, of spacing the supporting elements of the form too closely rather than too far apart. A well tied form for a fluted pier is shown in Fig. 92. The run moldings for the flutes are applied to a solid backing and the whole is erected as a panel. The ties are spaced on about 12x18-in. centers, which is probably closer than the concrete placing-rate required,

but the holes left by the pencil rods are so small that they will not be noticeable when plugged.

Inner and outer wall forms must be carefully aligned before the ties are tightened. If this is not done, the truss-like action of the walls acting together will make it very difficult to align the forms accurately. A method of aligning wall forms was described in Section XII.

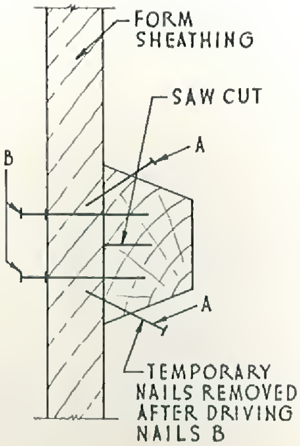


Fig. 93

Boxes, waste and wood molds, panels or anything applied to the main wall forms should be as lightly nailed as possible so that such parts will pull loose from the forms when stripping and will remain in the concrete. After the lumber has dried and shrunk, the ornamental detail forms can be removed easily without damaging the concrete.

It is well to use double-headed nails driven from the outside of the forms wherever possible, because they can be pulled easily, leaving embedded parts of the forms in the concrete temporarily. When applying rustication strips, for example, to the face-side of a form such as shown in Fig. 90, it is advisable to use the double-headed nails even though the strips are made with a draw. Fig. 93 illustrates the method of application. The strips are laid out in their proper location and just tacked in place from the inside with nails *A*. With one man bucking-up on the inside, another secures the strips firmly with double-headed nails *B* from the outside and the temporary nails are withdrawn. Six-penny common double-headed nails are usually sufficient for this purpose.

It is generally advisable, wherever possible (see page 29), to erect the outside forms first. A better job of applying the form lining can be done when a lining is used and waste molds can be more accurately set. Tie holes can be drilled from the face-side of the form thus avoiding burrs and allowing any pointing to be done more easily. It is also simpler and more economical to place reinforcing steel. A typical erection job is shown in Fig. 94. Vertical sheathing is shown at *A*, which is used as a tight backing for Presdwood lining *C*. The Presdwood below the level of the second-story window sills has been shellacked and oiled as shown in areas marked *D*. Plaster waste molds are in position at *B* and molds may be seen on the scaffold at *F* ready for erection. Window frames are set at *E*.

Construction joints should be located, as previously mentioned, where they will be least conspicuous, but it is sometimes necessary to locate them in flat wall surfaces where there are no architectural details to obscure them. By taking proper precautions, joints in such exposed locations need not be prominent enough to be objectionable. It is essential that there be no offset at the joint and no leakage. To do this, either a tie rod should be located 3 to 6 in. below the joint, or a bolt threaded at both ends should be provided to hold the forms above tightly against the hardened concrete as shown in Fig. 95. Unless the hardened concrete is at least four days old, a plate washer should be provided in addition to the nut to prevent breaking through the concrete. When the forms above the joint are stripped, the previously-greased bolt or tie is removed from the concrete. Wedges driven between the wale and the sheathing will help tighten the joint. A row of ties should always be located just above the joint to resist the pressure of the concrete. Dependence should not be placed upon bolt below joint for this purpose.

Fig. 92

A straight construction joint is less noticeable than an irregular one. To produce a straight joint, tack a 1x2 strip, as shown, to the lower form and bring the concrete just slightly above the bottom of the strip. If any laitance comes to the top of the concrete, it can be cut off with a trowel; the strip is removed after the concrete has set enough to hold its position. When the next lift of concrete is placed, there will be a straight true joint. The keyway shown in the illustration serves as a weather stop and as a key to hold the two sections firmly together.

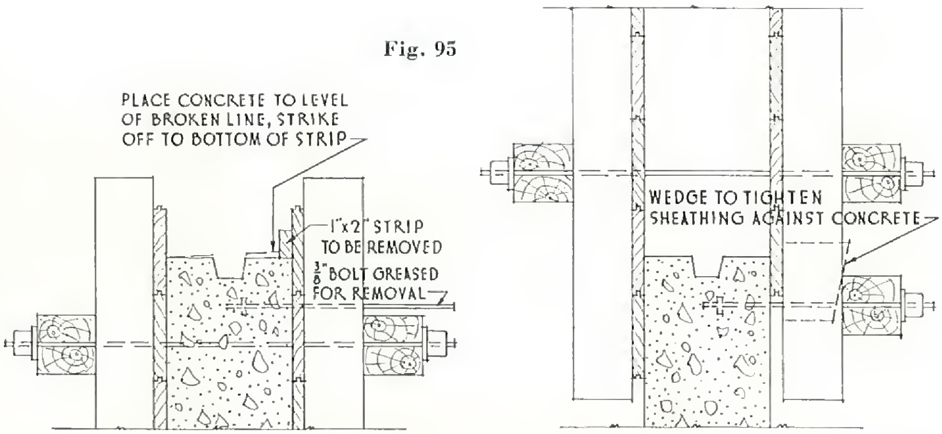
Oiling

Form oil can be helpful or detrimental to an architectural concrete job, depending upon how it is applied. There is less danger of breaking sharp corners if forms are well oiled so they will strip easily, but too

much oil will stain the concrete. A complete coverage should be obtained, but the film of oil should be as thin as possible. The surface of the form should just feel greasy, but there should be no free oil apparent.

All form lumber to come in contact with the concrete should be oiled before erection and preferably as soon as delivered on the job. It is also desirable to oil plywood on the ground because it can be done more thoroughly. A wide brush is suitable for the purpose (see Fig. 96). All surplus oil is removed with waste. Plywood oiled at the mill will require less oil on the job and more re-uses will be obtained. Linseed oil cut with kerosene is good for oiling plywood, but any one of the oils made by a number of manufacturers specifically for the purpose is satisfactory. Presdwood forms should be given a light coat of shellac before oiling, which is usually done after the Presdwood is applied and cracks are filled; metal mold must be thoroughly cleaned of all rust before oiling with a very light oil.

Fig. 95



Waste molds should be thoroughly dry before being given two coats of shellac. The molds should be shellacked before leaving the shop. After being set in the forms, and the joints filled and all patching done, the new plaster should be touched up with shellac. The molds must be greased with a light yellow cup-grease, which may be cut with kerosene if too thick. The grease should be wiped into all angles of the mold and every bit of surplus grease carefully wiped off. Care must be taken not to drop oil, grease or shellac onto hardened concrete or reinforcing.

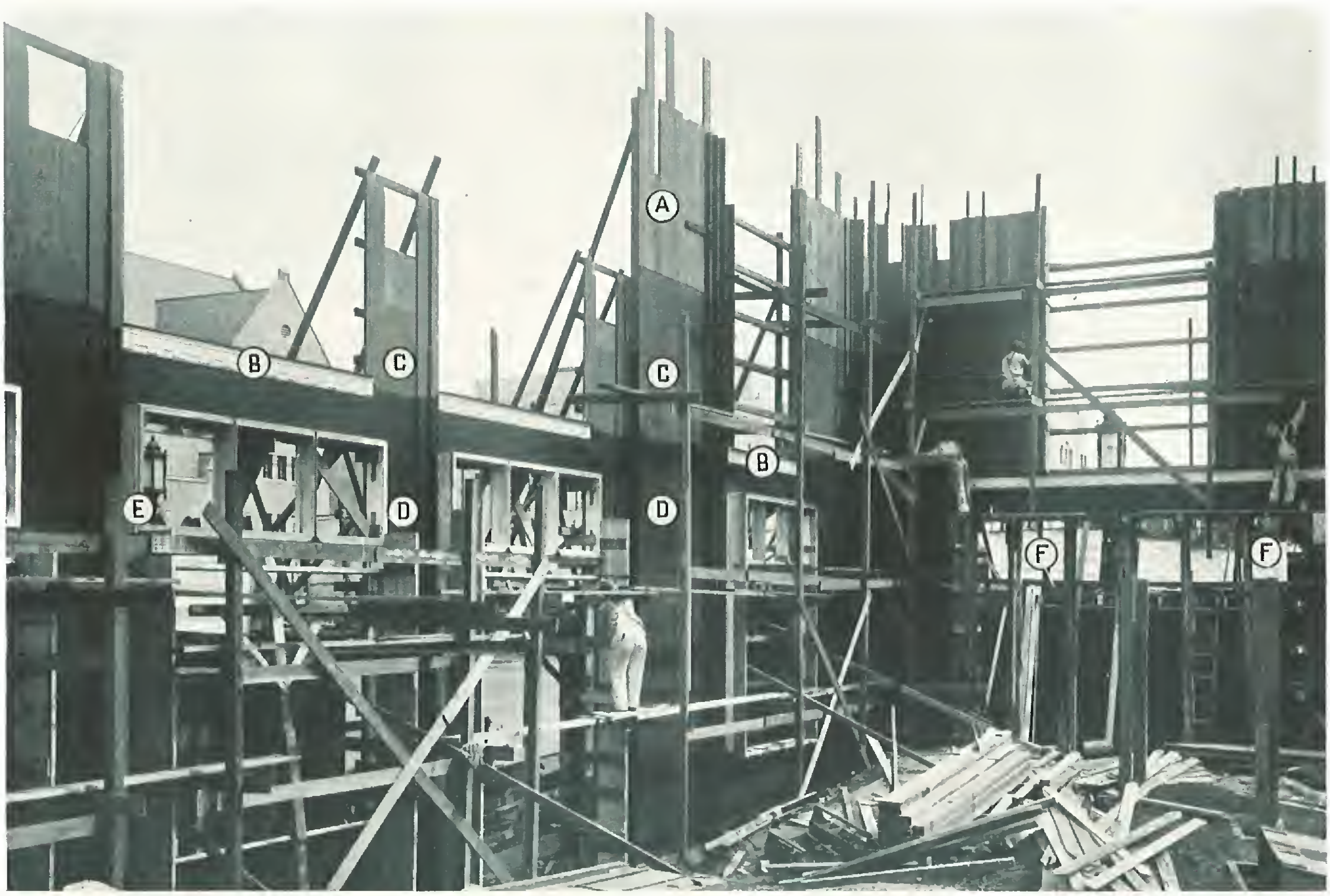


Fig. 94

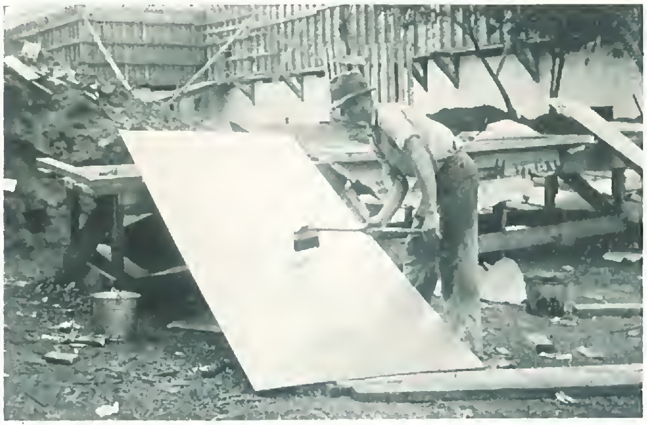


Fig. 96

Fig. 98

Stripping

Careless workmen can nullify the value of good detailing and planning by indiscriminate use of pinch bar and sledge. It is worthwhile to impress upon workmen that corners must not be broken nor surfaces damaged and that maximum re-use of material is desired. A little time spent in training the stripping gang in the order and manner of removing forms will result in a better and more economical job.

A pinch bar or other metal tool should never be placed against the concrete to wedge forms loose. If it is necessary to wedge between the concrete and the forms, only wooden wedges should be used.

As a rule, no forms should be stripped in less than three days after the concrete is placed. At that time, cut the ties on the face-side of the wall inside any kinks caused by the buttons. Pull the ties from inside the wall. The wales having been removed, the studs can then be loosened from the sheathing, as there will be sufficient spring in the long lengths of studs generally used in a built-in-place job. Fig. 97 is a good example of this stripping procedure on a job in which plywood was used as sheathing.

When stripping forms in the vicinity of a belt course, cornice or other projecting ornament, begin stripping some distance away from the ornament and work toward it. In this way, if there is any tendency for the forms to bind around the ornament, the pressure of the forms against projecting corners will be relieved so there will be less chance of spalling sharp edges.

Forms that are recessed into the concrete require special care in stripping. To remove rustication strips, for example, start at a corner, window opening, or some place where it is possible to get a wooden wedge behind the strips. The wedging should be done gradually and should be accompanied by light tapping on the strip to crack it loose from the concrete. Never remove a rustication strip or other embedded form with a single jerk after it has been started at one end. Such forms should always be left in place as long as possible so they will shrink away from the concrete. Fig. 98 shows the result of careful workmanship in forming rustication. Note some strips still in place. Where both ends of a form are tight against offsets in the concrete, if the form is made in at least two parts with the joining made on a 45° miter, stripping will be easier.

The stripping of waste molds should be entrusted to a man who is familiar with the detail. While proper greasing of the mold will facilitate stripping, the plaster will usually stick to the concrete, at least in the undercuts. This must be cut away with a cold chisel and the work must be done carefully. Waste mold should be left in place (see Fig. 99) until all other forms around are stripped and until there is no danger of damaging the ornament due to other work in the vicinity. The mold also holds the moisture in the concrete, affording good curing.

After forms are stripped, all material must be thoroughly cleaned of hardened concrete. Some concrete will always adhere to sheathing lumber in spite of thorough oiling. A tool made to fit the tongue and groove of matched boards will save time in removing concrete from the edges of boards.

All nails should be pulled from sheathing boards, plywood and Presdwood. Never bend nails over by

Fig. 97

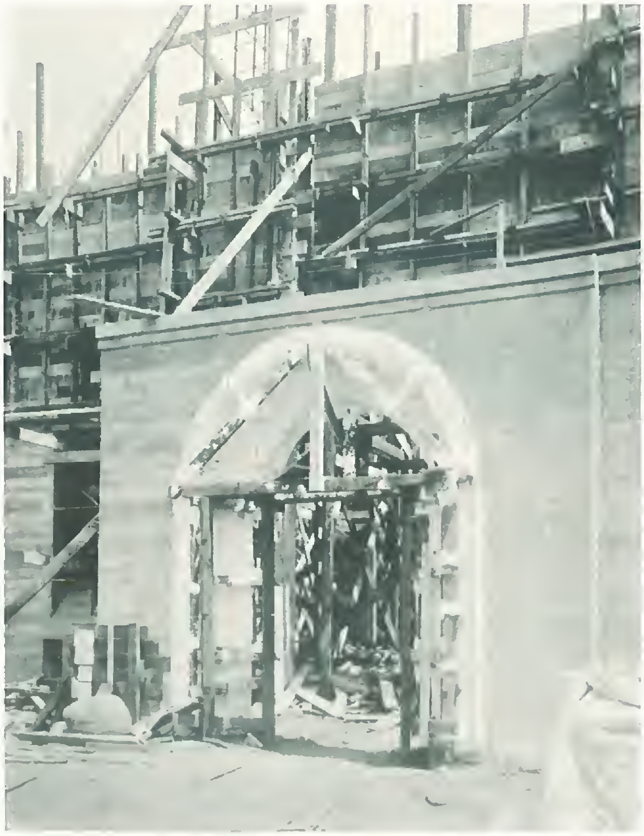


Fig. 99

hammering them against the face of the material. Holes which were bored through sheathing for form ties may be plugged by driving in common corks and cutting them off flush with a sharp chisel or fine saw. Patching plaster can also be used for this purpose.

Parts of boards that are split, or from which the tongue and groove have been broken, should be cut out to avoid loss of time in erection incurred when the carpenters must handle unusable material. Cleaned lumber should be sorted as to sizes and lengths and should be stored in neat piles. Plywood and Presdwood should be laid flat out of the sun to keep edges from curling.

SECTION XIV—ESTIMATING

A discussion of the entire subject of cost estimating is beyond the scope of this publication; therefore, only the general principles of estimating form costs will be considered.

Labor

The labor cost of fabricating, erecting and stripping forms is usually estimated on the basis of square feet of contact area. It is customary on a job with a normal amount of ornamentation to take off the total contact area as though the wall were plain. Window and other openings, unless very large, are figured solid. The area thus obtained is priced as though the wall were unornamented; the area of the openings figured solid will offset the greater amount of labor required to form them. Separate allowance is made for the ornamental details as explained later.

For plain walls with only an average amount of breaks and reveals, the labor cost for ordinary lumber forms for the exposed surfaces will vary between 10 and 12 cents a contact foot depending largely upon the hourly wage rate. The inside forms will cost about 2 cents a square foot less than the outside forms.

Plywood applied directly to the studs will cost slightly less for labor than 1x6 T and G boards, the difference being 1 to 2 cents a square foot, depending upon whether the wall is composed of large flat surfaces or is cut up considerably.

Thin plywood or Presdwood applied over tight backing will cost about 2 cents a square foot in addition to the cost of ordinary wood forms, as a carpenter can apply 40 to 50 sq. ft. of lining in an hour.

A careful study must be made of each ornamental detail to determine the additional number of hours of labor necessary to cut and fit the forms, set molds in place, provide extra backing and bracing, and to patch and point waste molds. An allowance must also be made for extra labor required for stripping waste molds, especially if there are many undercuts. These allowances for extra labor are generally added as a lump sum for each detail considered separately. Only through experience can these costs be established, because they depend upon the ability of the workmen and the foreman and upon the complexity and size of the detail. It is therefore important on each job that cost records be kept of the formwork for every ornamental detail, until sufficient data are accumulated on which to base future estimates.

As an indication of the average cost of installing waste and wood molds, the building illustrated in Fig. 100 in the following chapter may be taken as an example. The following costs are in addition to that for the plain wall area:

Niches—setting plaster molds, each					
2 carpenters	4 hrs. each	at	$1.00		$8.00
1 laborer	2 hrs.	at	.50		1.00
					$9.00
Fluted pilasters—fabricate and erect wood mold panel, each					
2 carpenters	3 hrs. each	at	$1.00		$6.00
1 laborer	1 hr.	at	.50		.50
					$6.50
Entrance—setting plaster waste mold					
4 carpenters	12 hrs. each	at	$1.00		$48.00
1 laborer	4 hrs.	at	.50		2.00
					$50.00
Belt course below name—setting waste mold					
2 carpenters	6 hrs. each	at	$1.00		$12.00
Name—attaching waste or wood molds					
46 letters at $0.20					$9.20

The cost of labor for cleaning and oiling forms is sometimes included in the square foot price of erecting and stripping. It is better, however, to keep such costs separate both when estimating and when keeping cost records. A laborer should clean hardened concrete from lumber, remove nails and oil the material for re-use for 1 to 1½ cents a contact foot of forms.

Material

Until sufficient experience is gained to estimate quite accurately the quantity of form material required by inspection of the architect's drawings and the contractor's key drawings, it is advisable to take off an accurate bill of material. All boards and dimension lumber should be listed according to sizes and lengths required for the various locations. A summary sheet can then be made, grouping the material of the same size into commercial lengths. Due allowance should be made for re-use of material and an allowance made for waste. The latter will amount to about 10 per cent each time the material is re-used. The waste on sheathing will be somewhat higher and on dimension material, appreciably less.

For rough estimating purpose, it can be assumed that 2½ to 3 board feet of lumber will be required for each contact foot of forms for one use; if no material were wasted and three re-uses were contemplated, the total amount of material indicated as necessary for the entire job should be divided by 3 to ascertain the quantity to buy. High walls and a rapid rate of placing the concrete will increase the quantity of material for each contact foot, due to closer spacing of studs and wales.

The cost of ties will depend upon the type used. If pencil rods are used, the only material consumed is the rods and a few buttons which may be lost. A charge of one cent a square foot of wall area will usually be ample for ties, nails and bolts.

SECTION XV—A TYPICAL JOB

The fundamentals of design and construction of forms for architectural concrete work have been discussed and illustrated in the preceding sections. Of necessity, many principles, methods and details have been considered more or less independent of the other factors, all of which should be taken into account on each specific job. As a summary therefore, in this chapter, the forms for a typical small building will be analyzed.

For the sake of brevity, only one elevation will be considered in detail. A picture of the completed building is shown in Fig. 100. The design is relatively simple, yet practically all types of forms or kinds of material discussed in this booklet either are required in the construction or might have been used in one of the alternative methods of forming the job. The method chosen for the purpose of illustration may not be the one used by the contractor, but it is a practical method which would produce good results economically.

Planning the Job

It will be assumed that the entire building has a volume of approximately 160,000 cu. ft.; the total contact area of forms including floors, roof and walls above grade is roughly 30,000 sq. ft. and the area of the front elevation is about 1,660 sq. ft.; for the purposes of this example, the total quantity of concrete will be taken as 700 cu. yd.

Fig. 100—Los Angeles County Medical Association Library, Los Angeles; Gordon B. Kaufmann, architect; Wm. Simpson Construction Co., contractor.

Speed of Erection and Type of Forms

The approximate time required for completion of the concrete work and the size of crew required to do the work are estimated in accordance with the rules given in Section V.

Assuming that panel forms can be used, except for the front elevation which does not lend itself to forming with panels because of the ornamental detail, approximately 16 carpenters and 8 helpers will fabricate, erect and strip the forms for the entire building above grade in about three weeks. Allowance for building the front wall forms in place and for the ornamental detail will add roughly three days to the required time for forming.

Setting of reinforcing will proceed during the erection of forms and will not appreciably add to the duration of the job.

Using a ½-yd. mixer and a crew of 25 laborers, roughly six days will be required to place the concrete.

Time Forms Must Remain in Place—Re-use of Forms

To avoid delay while waiting for forms to be stripped, sufficient material will be provided to form the entire building up to the construction joint *B* at the belt course just beneath the building name shown in Fig. 101. One re-use of a part of the form lumber will thus be obtained. Some allowance may be made for using most of the wales from the first story in the story above before the balance of the first-story form material has been removed.

Construction Joints

Two of the three joints in the front elevation are located where they are concealed by architectural details. The lowest joint is at the floor-level and follows the outline of the pediment over the doorway and the niches at each side. It is convenient to locate the joint at the top of the floor slab, but it would be slightly less noticeable if raised to the level of the top of the niches. With horizontal joints located as shown, vertical stoppings dividing the building into two parts will be needed to keep the quantity of concrete to be placed in a day within capacity of the plant and crew.

Order of Erection

The building is the type described under Plan 1 (page 29) and the order of erection suggested there will be followed, namely:

1. Erect outside wall form and bring to alignment.
2. Erect inside wall forms and floor forms.
3. Check alignment, tighten braces and bolts.

Erection Methods

The front wall forms will be built in place and other forms will be in panels small enough to be handled by hand or with a hand-operated "A"-frame hoist. The job is too small to warrant power equipment for form erection.

Order of Stripping

In general, the order of stripping will be the reverse of the order of erecting the various parts of the forms. This subject will be considered more fully in the discussion of the form details.

Detailing

Figs. 102 and 103 are typical of the key drawings necessary to show the form details for this job. Addi-

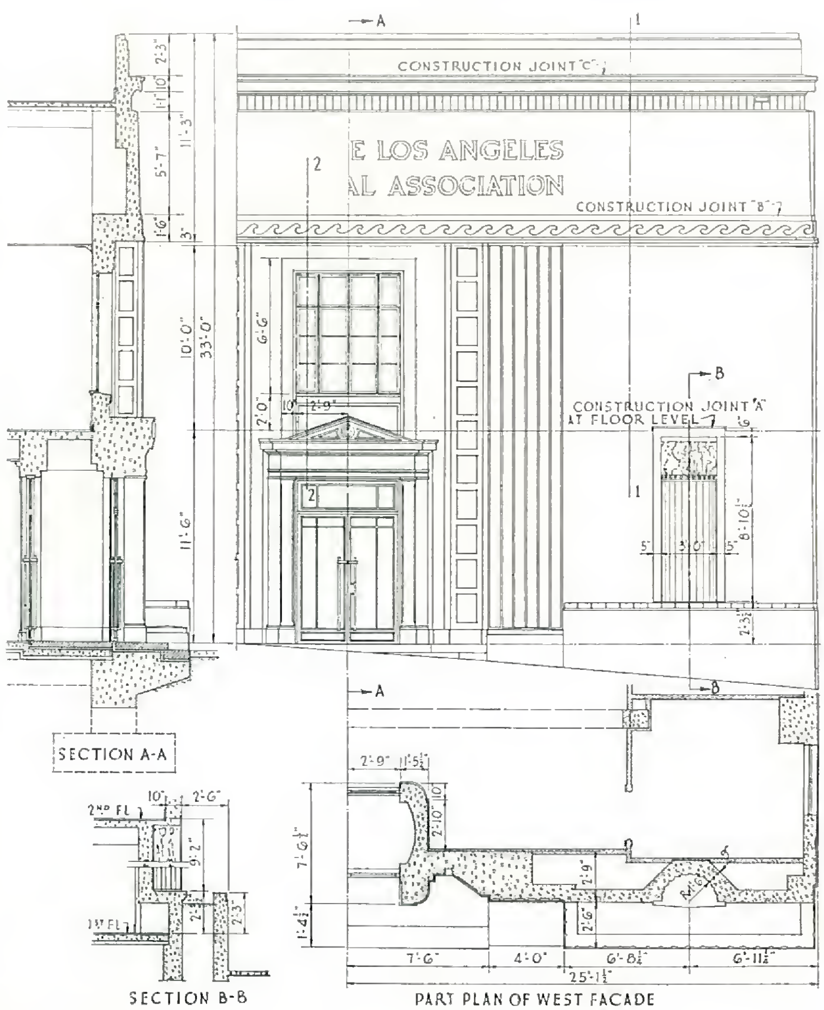


Fig. 101

tional details or sections would be required to show the forms for steps, flower area curbs beneath niches and for other incidental details. In order to illustrate the tying and bracing of the forms, the studs, wales and ties are shown, which is not customary on contractor's key drawings. Likewise, in order to avoid confusion in the small scale drawings, dimensions of all the details which should be shown on job drawings have been omitted.

The architect's design calls for a relatively smooth wall surface; so plywood is adopted as the form sheathing. Five-eighth-inch plywood is applied directly to the studs. Ordinary boards or plywood may be used for the inside forms without material difference in cost. Twenty-four-inch wide sheets produce a jointing in keeping with the proportions of the building and are slightly cheaper than wider sheets, so 24x48-in. or longer sheets will be used.

Either plaster or wood letters will be satisfactory. The choice will depend entirely upon price. The belt course and cornice are shown formed with plaster molds because the amount of repetition will undoubtedly make waste molds more economical than wood. Plaster molds have been used for the columns at the entrance and for the niches, although it is possible wood molds for the fluting in the niches would be more economical. For such details it is often desirable to get mill and waste moldmaker's prices before making a final decision. The fluting at the sides of the entrance can best be formed with wood molds as shown.

The height between construction joints is less than 12 ft. so a 2 ft. an hour placing-rate would be adequate to complete a section from joint to joint in six hours. It is not advisable however, to figure on less than a 3 ft. an hour rate. If the work is to be done in the summer with an average temperature of 70° F., a maximum pressure of 430 p.s.f. will be exerted on the forms. According to Table 9, the stud-spacing should not exceed 16 in. and from Table 11, assuming 2x4 studs *S4S*, the wales should not be spaced more than 28 in. apart. If double 2x4 wales *S1E* are used, the tie-spacing can be obtained with sufficient accuracy by mental interpolation from Table 7 as 34 inches. From Fig. 9 the required size of tie is found to be ½ in. round.

Note in Sec. 1-1, Fig. 102, that the outside forms at construction joint *A* lap over the hardened concrete and are secured by a bolt embedded in the concrete. At the other two joints this is not necessary because there is an offset in the architectural design at those places.

The offsets and deep reveals in the elevation and the batter on the wall complicate the forming slightly, although no serious difficulties are encountered. Because of the width of the offsets near the roof line, the studs should be lapped as shown to insure ample rigidity.

The provision made for holding corners and angles

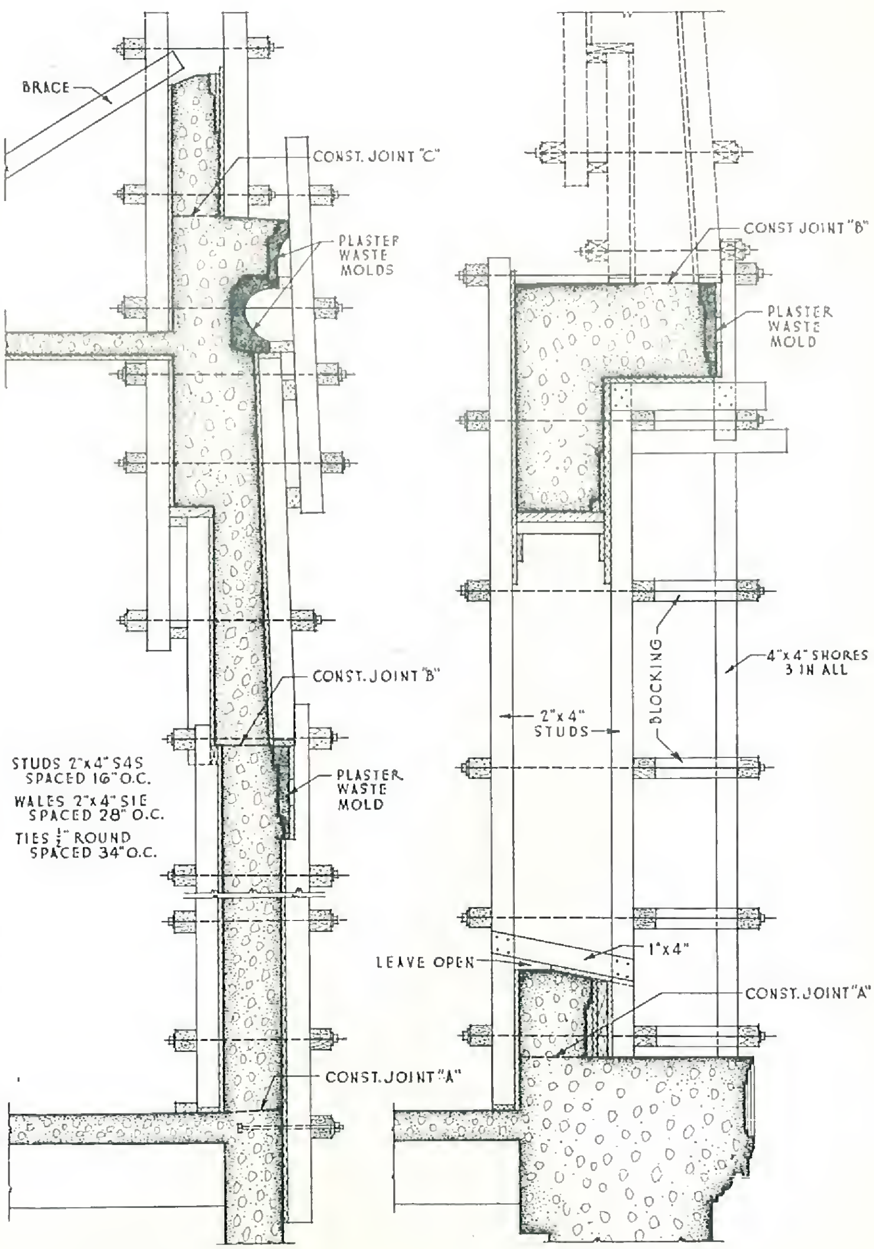


Fig. 102

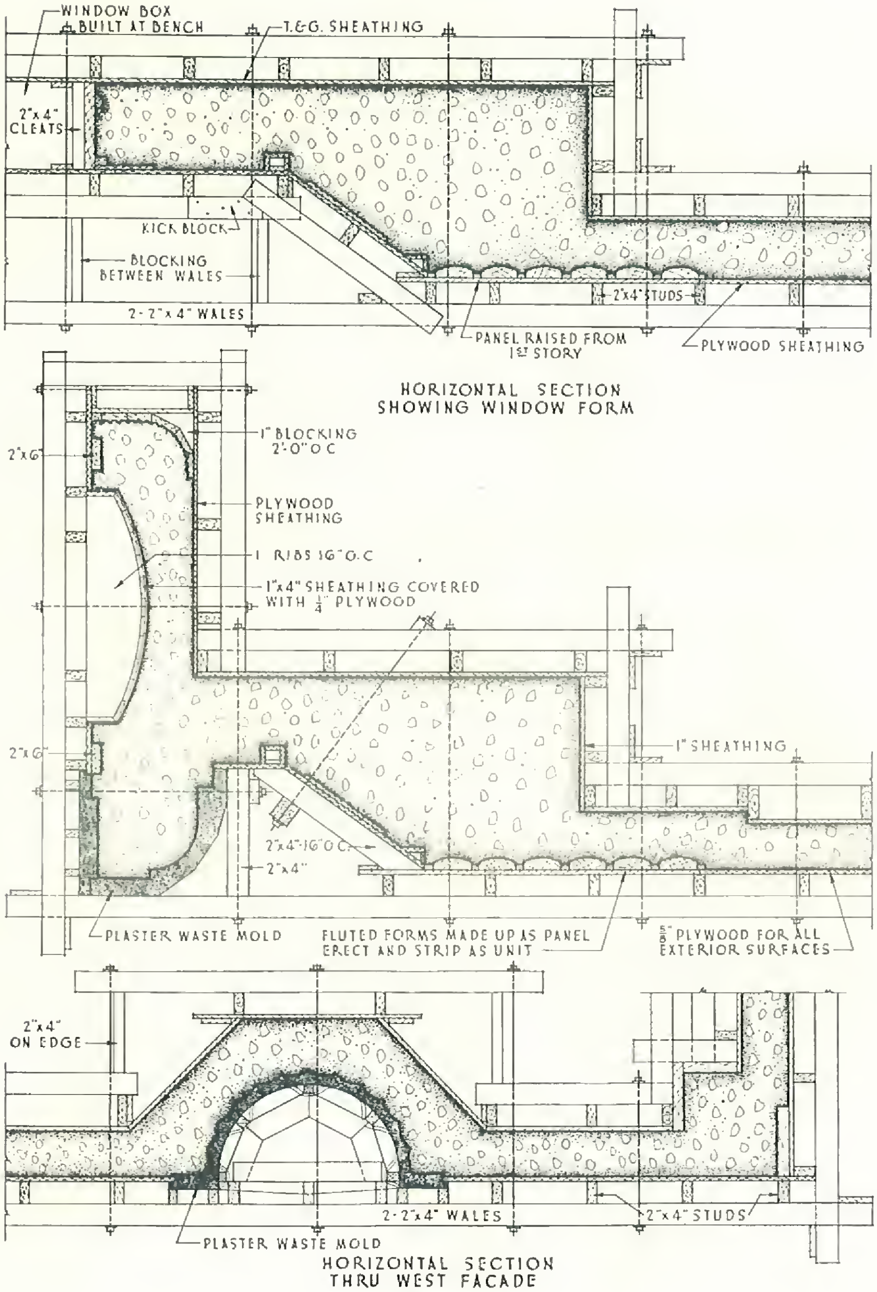


Fig. 103

of forms tight should be carefully studied. Ample ties, tight joints and solidly blocked corners are of utmost importance. The wood molds for the fluting are shown applied to a solid backing which will hold the joints tight and that part of the forms can be moved up as a panel. Note that the joint between the panel and the adjoining form is made at a stud.

The forms for this job are very easy to strip. The tie rods are first cut on the outside between the wales and the sheathing. At the same time, the kick-strips holding the intersections of the wales are knocked off. The wales may then be removed. Next the studs should be removed from the sheathing, except where the wood molds for the fluting are to be moved as a panel. As the studs are pried up, beginning at the bottom, the plywood sheets will be loosened from the concrete and can be removed without damage, if the sheathing has been lightly nailed to the studs. The waste molds should be removed last and only after all work in the vicinity has been completed.

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